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STUDIES ON MILK EJECTION IN THE DAIRY COW

THE EFFECT OF STIMULUS ON THE RELEASE OF THE "MILK EJECTION" HORMONE.

By W. G. WHITTLESTON, Ruakura Animal Research Station, Department of Agriculture, Hamilton.

(*Received for publication, 29 March 1949*)

Summary

Experiments are described which demonstrate that a cow is able to respond to a stimulus applied after milking by secreting a second lot of "milk let-down" hormone. Milking two quarters at a time by machine, the normal decline in yield of the second pair was shown to be arrested by a second stimulus prior to the second milking. Milking four quarters at a time and using a double machine milking procedure the first ejection curve was shown to be inhibited in proportion to the level of electric shock applied to the cow before milking while the second milking curve tended to normality as the first milking was increasingly inhibited. The effects due to varying the time at which the cow is shocked suggest that the inhibition is mainly due to the conditioned reflex component of the mechanism.

The behaviour of the cow, which under field conditions yields a considerable amount of her milk to hand stripping following machine milking, is explained in terms of a conditioned double secretion of milk let-down hormone.

INTRODUCTION

It is a well-known fact that many cows yield a pound or two of milk when hand milked after the teat cups of the machine are removed. This phenomenon is accounted for by Petersen (1) in terms of a mechanical blockage of the "annular fold" at the top of the lumen of the teat due to the "crawling" upwards of the teat cups. As the udder slackens due to the withdrawal of milk more and more tissue is drawn down into the partially evacuated teat cup and finally milk flow ceases as a result of the orifice at the top of the teat lumen being closed. By pulling the teat cup downwards, so eliminating the obstruction, the last of the milk may be withdrawn by the machine. The writer (2) has measured the amount of milk given as "machine strippings" following the pulling down of the teat cups for 12 cows throughout a lactation. The averages for the 12 cows (in pounds) were:—

0.69, 0.83, 0.45, 0.51, 1.21, 0.72, 0.65, 0.71, 0.74, 0.53, 1.12, 1.22.

The herd average was 0.79 lb. of milk.

It is interesting to compare these figures with the results of the following experiments.

The experiments were intended to determine the amount of milk which can be drawn from a cow before the "let-down" reflex has come into operation. The reflex was inhibited by a shock from an induction coil administered prior to milking. This resulted in a delayed ejection curve (Fig. 1) recorded on the electrical instrument previously described (3). The delay was long enough to enable accurate measurements

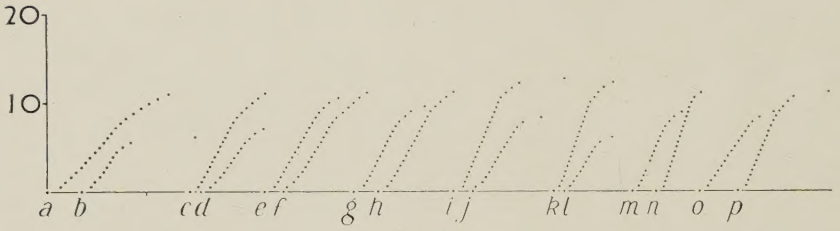


FIG. 1

of the preliminary milk flow to be made. This was done by diverting the milk from the cow into an evacuated glass vessel for a given period of time. The milk flow was then switched back to the cylinder of the recording instrument and a complete milk ejection curve plotted in order to check on whether the cow was responding normally or not. The results are set out in the following table.

TABLE I.

Expt. No.	Vacuum in Machine. (In. Mercury)	Treatment.	Preliminary Rate of Flow. (lb./min.)	Amount of Milk. (lb.)
1	15	Normal	0·24	
2	10	,,	0·5	
3	14	Teat cups pulled	1·25 for 55 sec.	1·14
4	14	Normal	0·08	
5	14	Teat cups pulled	1·10 for 1 min.	1·10

It would appear from the above that there is a small preliminary flow of milk from the cow before the let-down reflex operates. This flow rate is increased by pulling down on the teat cups, and when this is done the milk cistern empties in about a minute. The series of results given is typical of a number of similar determinations but definite conclusions cannot be drawn until a number of different sorts of cows has been studied. The main limit to this type of experiment lies in finding cows which give a suitable delayed let-down after inhibition.

The results indicate that the teat cups "crawl" prior to the letting down of the milk and show that the amount of milk which can be drawn in these circumstances is of the same order as that due to machine stripping.

Before proceeding to our main problem one point may be noted. The preliminary rate of flow under normal conditions actually decreased with increased vacuum. Earlier experiments (4) have shown that average milking rate is not directly proportional to vacuum. This may partly be explained by the crawling of the teat cups causing a partial blockage before the milk starts to flow into the cistern. When the milk is let-down

the degree of crawling adjusts itself roughly to the rate of milk flow into the cistern. This gives rise to a situation in which an increase or decrease of vacuum would not markedly affect the flow rate except in the case where the teat sphincter is the limiting factor, i.e. during the flush for most cows or in the case of the tough milker.

It is evident from the foregoing results that "crawling" of the teat cups as described by Petersen is a very real phenomenon. It would, however, appear to be associated with the retention of amounts of milk of the order of the volume of the milk cistern. In other words, milk given to the "machine stripping" process following normal machine milking will be of the order of a pound or two in quantity and it will be delivered as soon as the teat cups are pulled. This is a marked contrast with another type of stripping problem often encountered by the practical dairy farmer. Many herds contain cows which will give half to two-thirds of their milk to the machine but only yield the remainder after a considerable amount of vigorous machine stripping accompanied by udder massage or after normal hand stripping. Following this treatment the cow yields a "second flow of milk", to use a farmer's phrase. The writer proposes to discuss experiments which support the view that in such cases the cow does actually respond to the stimulation with a further release of pituitary milk ejection hormone. Before so doing, a brief review of some of the literature will be given as a background to the work. The first clear explanation of the ejection process as separate from the secretion of milk was given by Gaines (5) in 1915. This investigator showed that pituitary extract causes contraction of the mammary musculature, so forcing out the milk; that nursing, milking, and the insertion of a cannula, cause a reflex contraction of the gland musculature with resultant expression of milk, the reflex having a period of delay varying between 35 and 60 seconds, and that the reflex is destroyed by anæsthesia. The effectiveness of different stimuli was shown to vary. The following have a decreasing order of effectiveness: nursing by the young, milking by hand, insertion of a cannula. The recovery of the young after separation increases the natural reflex. Pituitrin has an even more marked effect than the latter. Gaines quite clearly showed that all of the milk is present prior to milking and is expressed (let-down) reflexly by the contraction of a muscle mechanism in the udder. He does not definitely state that he regards the reflex secretion of a pituitary hormone as the mechanism controlling the mammary muscles. This is implied, however, in the observation that pituitrin has a marked effect on the mammary musculature, and in the statement that the let-down follows a delay of 35 to 60 seconds after stimulation. The implication of Gaines' work is followed by Ely and Petersen (6) who present evidence for the view that the ejection of milk at milking time is due to a reflex secretion of a hormone by the pituitary gland (posterior lobe) following the stimulation associated with the normal milking process. Miller and Petersen (7) show that if a cow is stimulated to let down her milk some time (twenty minutes) before the milk is removed, there is a loss in yield. This is interpreted as being due to the hormone being dissipated in the cow's blood. Such an interpretation is only valid if the assumption is made that the cow does not secrete another lot of hormone following the stimulation associated with the milking machine. Knodt and co-workers (8) show that cows may be stimulated 2, 5, 10, and 20 minutes before milking

over a period of 90 days without influencing production. The contradiction between these results and those of Miller and Petersen may be resolved by either of two explanations: (1) The rate of destruction of the hormone is not the same in the two cases; (2) the cows may respond to the action of the machine by secreting a second lot of hormone. The former explanation raises an interesting point. Petersen and Ludwick (9) show that the let-down substance in cow's blood is totally destroyed in 30 minutes. Using a similar mammary gland perfusion method (10) Peeters and co-workers (11) show that the hormone is still active in the isolated gland after 80 minutes. Some considerable difference in the rate of destruction of the hormone is evident. In the case of women, Page (12) has shown that during a normal pregnancy between the fourth and the thirty-eighth weeks there is a thousand-fold increase in the blood concentration of an enzyme (pitocinase) capable of destroying the oxytocic substance from the posterior pituitary gland. This substance is precipitated by 1/3 saturated ammonium sulphate and so is apparently a large molecule. Near term it reaches a level capable of destroying half of a given amount of oxytocin in 45 seconds (the reaction is monomolecular). If we adopt Petersen's view that the milk let-down hormone is the oxytocic substance from the posterior pituitary body it will be evident that a rise in concentration of a pitocinase in cow's blood will cause differences in the milk ejecting ability of the cow as the lactation advances and will tend to cause the cow to dry off. We have observed a tendency for the letting down of milk to become erratic towards the end of the season (2). This cannot be explained as due to a partial failure of the conditioned reflex mechanism but is explicable in terms of an enzyme system which destroys the let-down hormone at an abnormally high rate towards the end of the season. It is interesting to note that many farmers strip their cows only towards the end of the season. If such a stripping process can evoke a further secretion of let-down hormone it may be justified in the light of the foregoing discussion.

The latter explanation of the difference between the results of Knodt *et al.* (8) and Miller and Petersen (7) is the one of immediate interest in the present discussion as it would be the more likely for a herd of cows in full milk. That cows can be trained to respond to the action of the milking machine as the chief stimulus to let-down is well known. In earlier experiments (13) the author has described cows trained to require about one minute's pulsation by the milking machine before the milk would be let down. After the flow had started the pulsator could be shut off with no ill-effects. On the other hand, if the machine were applied with the pulsator out of action the milk was not let down. With the different shed routine used for the study of milk ejection curves throughout a lactation (2), it was found possible to milk the herd out completely without the pulsator of the machine operating. These results indicate that it is quite possible that in the one case the cows did not respond to the action of the machine while in the other case they did. One further condition is required, viz., that in the case of the cows milked by Knodt *et al.* (8) there was a second release of hormone adequate to cause an effective letting down of milk a second time. In what follows evidence is presented for this possibility.

Reverting to the problem of stripping, if a cow can let down her milk more than once, is it not possible that the really "strippy" cow is one in which a full response by the pituitary gland is not evoked by the

machine milking procedure and when the more stimulating process of hand milking starts there is a further and perhaps more copious release of pituitary hormone causing the ejection of the normal balance of the milk? Viewing the cow in historical perspective this seems not unlikely. The natural cow was not intended to eject most of her milk twice a day. Rather she was intended to deliver her milk "little and often" to a calf whose hunger was not confined to regular meal hours. The let-down mechanism would then be such as to produce enough milk for a feed when stimulated at any time. If this is so the modern cow has been compelled by breeding and training to depart from nature not only by secreting enormous amounts of milk but also by producing enough posterior pituitary hormone to enable man to get all of her normal yield of milk out twice a day. It is not surprising then that there are encountered in most herds some cows which are troublesome to milk by machine.

A further point which may help to explain some of the cow's variability in responding to the milking stimuli is the well-known fact that by injecting pituitary (posterior lobe) extracts more milk can be obtained even after an apparently complete milking (6). This is clearly demonstrated by the experiments of Dodd and Foot (14) who show that only 71.3 - 80.8 per cent of the milk and 39.3 - 48.5 per cent of the fat are given to the machine, the percentages being calculated on the basis of the "total" milk and fat obtained after injection of oxytocin following the normal milking of eight cows. It is quite clear that a "normal" response cannot evacuate the udder. In fact, it would appear that the neurohypophysis is not capable of producing enough milk ejection hormone to cause a complete emptying of the udder. It is interesting to speculate on the possibility of increasing the effectiveness of the milk ejection reflex. Of course, the fact that pitocin, when injected, can evacuate the mammary gland suggests the possibility that its action is "unphysiological" and raises the question of whether a separate hormone is involved or whether pitocin is the milk ejection hormone as suggested by Ely and Petersen (6).

In discussing the efficiency of any milking procedure "complete" milking must refer not to total evacuation of the udder but to the maximum normally obtained yield.

In what follows, the results of experiments will be described which demonstrate the probability of the view that in some cases when a cow yields a lot of milk on being hand stripped, she does so because of the secretion of a second dose of pituitary hormone following an inadequate stimulation by the machine milking procedure.

EXPERIMENTAL

The response of the cows to the treatments listed was recorded by the apparatus described earlier (3). All milking was done by a simple orthodox machine using a slide pulsator working at a 40:60 ratio and a rate of 42 pulsations per minute. The vacuum was $14\frac{3}{4}$ in. of mercury and was maintained precisely by an accurate weighted relief valve. The teat-cups were of the telescopic type using soft inflations tightened and changed regularly so that a constant tension was maintained. The end of milking was determined by means of a flow-indicating sight glass set to clear at half a pound of milk per minute (2).

It is well known that by milking a cow slowly one obtains a reduced yield of both butter-fat and milk (15, 16, 17, 18). This is explained

by the theory of Ely and Petersen already referred to (6) as being due to the destruction of the let-down hormone in the blood. A test of the possibility of a second let-down was made, using the fact that if a second lot of hormone is secreted the decline in milk yield due to this cause will be arrested.

Two cows were used in the first experiment. They were milked two quarters at a time by the machine with a constant period of time between the start of the milking of the pairs. One fore- and one hind-quarter made up the pair and the pairs were milked first alternately, i.e. if the right hind- and left fore-quarters were milked first on Monday, the left hind and right fore would be milked first on Tuesday. By this means the differences between the quarters were cancelled. Milk ejection curves were recorded for all afternoon milkings throughout the experiment, morning milkings being normal so as to even up the quarters when the second milking of the preceding afternoon was incomplete.

The following quantities were measured off from the curves:—

Total weight of milk delivered up to an end point of 0.5 lb./min. – W.
The time taken to reach a flow rate of 0.5 lb./min. – T.
The average rate of milk flow – W/T.
The gradient of the straight line part of the milk flow curve – W/T. max.

The quantities are given in pounds and minutes.

The experiment was divided into four periods, the treatments being as follows:—

PERIOD 1.—The first pair of teats was milked following washing and the taking of a squirt from each teat into the strip-cup. The cups were put straight on to the second pair of teats without any further preparation at the end of a period of 18 minutes following the application of the cups the first time. In both cases the teat cups were applied for seven minutes. The period lasted seven days.

PERIOD 2.—The first pair of teats was treated as in Period 1 while the second pair was treated as if milking were being commenced, i.e. they were re-washed and squirts taken into the strip-cup. This period lasted 10 days.

PERIOD 3 was identical with Period 1.

PERIOD 4 was identical with Period 2, except that the interval between the putting on of the pairs of cups was 12 minutes, the milking time for each pair four minutes and the duration seven days.

RESULTS

The results of the experiment are set out in summary form in the following table:—

TABLE II. DIFFERENCES BETWEEN FIRST AND SECOND MILKING
(Per cent.)

Period.	W.	T.	W./T.	W./T. Max.
Cow No. 261				
1	−34·8	−34·5	0	0
2	− 5·43	−16·1	+15·1	+13·6
3	−31·8	−20·5	−19·6	−14·1
4	+ 3·95	+3·20	0	+11·0
Cow No. 262				
1	−43·2	−28·4	−22·6	−22·2
2	+ 6·33	− 8·30	+17·7	+12·7
3	−36·4	−18·3	−15·5	− 8·67
4	−14·2	−15·9	+ 8·0	+11·6

During the first period of the experiment both cows show a highly significant decline in the amount of milk given at the second milking. This is also evident in Period 3. These results confirm the well-known fact that slow milking tends to cause a fall in the amount of milk obtainable. The differences between the milkings for Periods 2 and 4 are not significant. In the case of cow 261 in Period 4, the second quarters milked gave more milk than the first. In this period, cow 262 gave less milk for the same quarters though she had given more in Period 2. None of these differences, however, reach significance. It would appear that as a result of being stimulated again just before the second milking the quarters were evacuated normally, i.e. as a result of stimulation a second lot of hormone was released. The fact that in two of the periods more milk was obtained during the second than during the first milkings would suggest that the second release of hormone is no less efficient than the first.

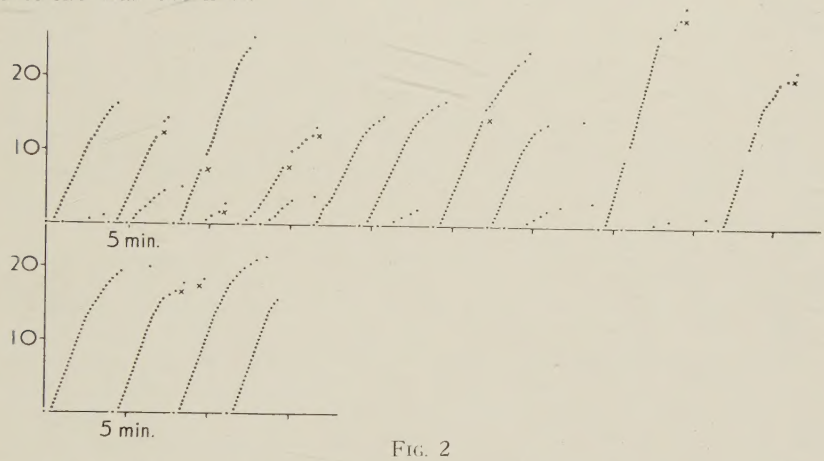


FIG. 2

The milking time tends to follow the amount of milk given. Thus cow 261 shows a significant (five per cent) decline in milking time for Period 1. Cow 262 shows a highly significant decline for the same period. As she is a more uniform animal in this respect, though the difference is smaller, it is significant at the one per cent probability level. The differences for Period 3 are not significant though both are negative. The other periods show smaller differences none of which are significant. Actually cow 261 shows a longer milking time for the last period though all the other differences are negative. The fact that the differences for Period 3 have lost significance suggests that the cows are becoming conditioned to the double milking procedure.

Both average and maximum milking rates do not show any significance in the differences between the groups. The figures do, however, show trends. In all cases during the periods when the cows were not stimulated prior to the second milking the maximum and average rates were either the same, as in Period 1 for cow 261, or less, as for all other cases. When the cows were stimulated prior to the second milking, the ejection rates all increased. These figures fit in with the idea that following the second stimulation there is a further release of milk let-down hormone.

Milk flow curves showing the general trends of the above experiment are shown in Fig. 2.

The second experiment in the present series employed the two cows used for the experiment described above. These animals had become used to being milked twice by the machine at each milking. It was thought worthwhile to continue the double milking procedure but using four sets of teat cups so that the udder was milked out normally, and to record the milk flow from the second milking following a definite period after the application of the cups the first time. The cows were started normally and after 12 minutes the cups were again applied following a second starting procedure. After a week the period between the milkings was increased to 18 minutes, all other conditions remaining the same. In the latter case the cups were left on for seven minutes regardless of the time actually required to remove the milk. In the light of the previous experiment it is probable that the second stimulation of

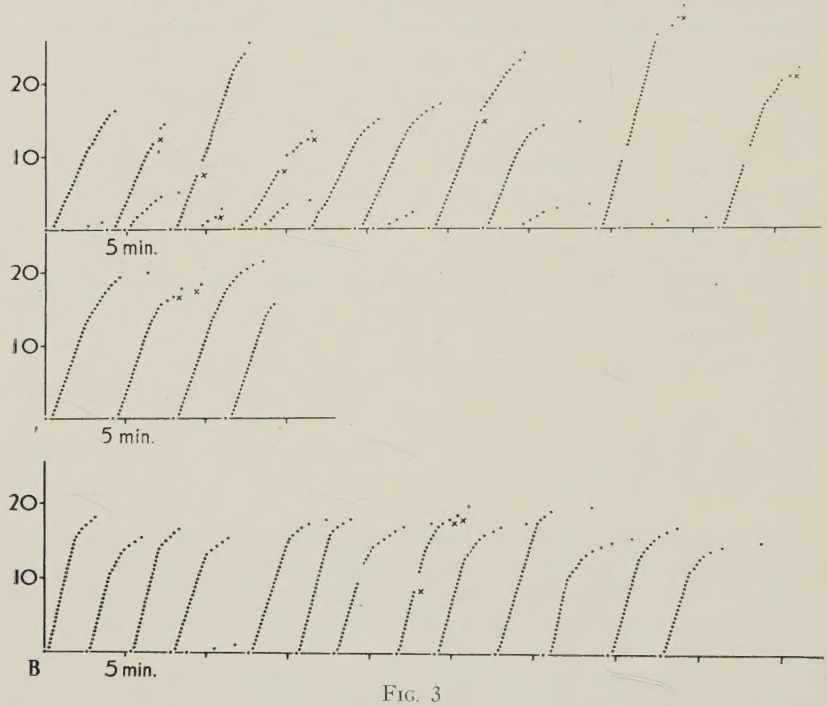


FIG. 3

the cow caused a second secretion of let-down hormone. The nature of the second milk-flow curve is, therefore, an index of the efficiency of the first milking. When the first milking is really effective no milk is obtainable at the second milking. The results for cow 261 are set out in Fig. 3A while the curves for cow 262 are given in Fig. 3B. A summary of the milk weights is given in the Table (Table II).

Cow 262 does not yield any milk at the second milking. The other animal does yield a varying amount which tends to become less throughout the experiment. The fact that this small amount of milk cannot be obtained by machine-stripping immediately after the first milking is interesting, though it is possible that it may be due to a draining of the ducts during the period between the two milkings and may, therefore, not be due to a second ejection. Cow 262 is seen to be the ideal machine milker. All of her milk is available to the machine and no more is obtained if she is stimulated again after milking. Cow 261 tends to give

strippings. There is a suggestion in the figures that when the first milking is down a little, the strippings make up for it. In other words, if the first stimulus is not as efficient as usual the milk is obtained the second time. This is common farming experience and seems to preclude the idea that the strippings are entirely due to drainage of the ducts. Before describing the next experiment which demonstrates the effect of inhibiting the first let-down of milk, two points should be discussed which emerge from the above results. Firstly, in the paper already referred to, Gaines (5) records the fact that in the goat, after an apparently complete hand-milking, the kid is able to obtain more milk. He shows that this second stimulus results, after a delay period, in a distinct flow of milk. The explanation is evidently that there is a further release of the pituitary hormone when the more marked stimulation associated with the kid's nursing is experienced by the mother. This indicates that hand-milking in this case may not be a very efficient stimulus. Gaines presents figures to show that in the case of the cow, the machine may not evoke an efficient let-down and hence more milk is obtained when the cows are hand stripped. Secondly, in the paper of Miller and Petersen (7) previously discussed an experiment is described in which the effect of a 15 minutes delay in stripping the cow is examined. The results show that the cows gave slightly more strippings after the delay than when they were stripped immediately after milking. The authors conclude: "Milk as strippings is not forced down at the time of stripping as is the first drawn milk. This portion of the milking is not under pressure at this stage, hence it is not removed by the machine. The apparent increase in the strippings might be due to drainage from the large ducts during the 15 minute interval." The author's explanation of the results, which apparently contradicts the view of Miller and Petersen that most milk is obtained by fast milking, is that stripping causes a further contraction of the mammary musculature and so the squeezing out of more milk. This residue may, therefore, arise due to an incomplete first milking, the secretion of more milk during the delay period, and to some small extent to the draining of the ducts.

The third experiment in this series deals with the effect of inhibition on the milk-flow curve. The same pair of cows was used for these experiments as we used in those described above. As these animals were accustomed to the double milking procedure this was a convenient arrangement. Throughout the experiment an 18-minute period was maintained between the beginnings of the two milking periods with the cups being kept on for seven minutes. In order to avoid the building up of a marked conditioned reflex and to eliminate as much as possible the psychological interaction between the two cows when the electric stimulus was applied, one cow was milked without shock while the other was electrically stimulated, the order being reversed the next day. All morning milkings were normal.

The electrical stimulus was supplied from a large induction coil. The level of stimulation was varied by altering the number of quarter-second pulses applied. The current was applied to the cow via a small brass weight tied to the wire leading to the coil and resting against the cow's flank. One of the cows, 261, was subjected to increasing shocks on alternate days throughout the experiment; the other cow started with the maximum shock which was subsequently decreased. The teat cups of the machine were applied in all cases one minute after the shock.

The results of the experiment are set out in the accompanying figures. The milk ejection curves are:—

(a) First-milking curve.
(b) Second-milking curve.
(c) Control curve recorded on the previous or following day at a double milking without electric shock—1st milking.
(d) The second-milking curve, if any, for the non-inhibited (control) milking.

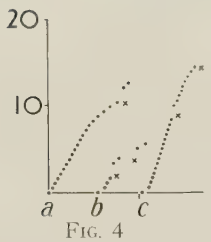


FIG. 4

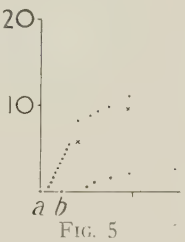


FIG. 5

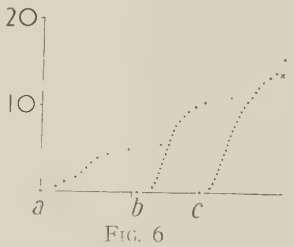


FIG. 6

Cow 261.—Fig. 4. Shock: Two ¼-second pulses.

The effect is a reduction in the milk-flow rate and in the amount of milk delivered at the first milking. The second milk-flow curve is quite significant in total volume. The control curve given is for the previous day's milking. No second curve was given. On the subsequent day the cow was annoyed by flies. This produced a distinct inhibiting effect which was somewhat less marked than that due to the electric shock. The effect of the flies is shown by the first and second milk-flow curves in Fig. 5.

Fig. 6. Shock: Four ¼-second pulses.

This time the first milk-flow curve shows a lower rate and quantity than the second curve. Again the control curve (recorded next day) is complete and there is no second milking. The control curve shows the same total amount as the sum of the two curves from the inhibited milking. In the previous case the control curve was less than the sum of the inhibited milk-flow curves.

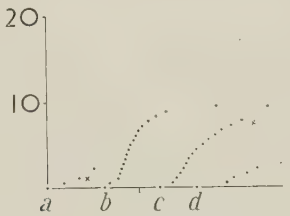


FIG. 7

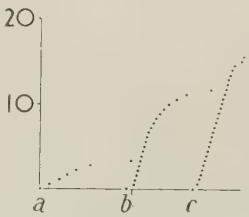


FIG. 8

Fig. 7. Shock: Eight ¼-second pulses.

The first let-down of milk is almost completely inhibited while there is a normally shaped curve for the second flow. The control curves for the next day's milking are far from normal, again due to an attack of flies. The importance of avoiding any disturbances to the normal routine in milking is well demonstrated by the curves.

Cow 262.—Fig. 8. Shock: Twelve ¼-second pulses.

This shock did not completely inhibit the first milking. The second curve is in many respects normal though it shows a much more curved characteristic than the control. No second flow was obtained at the second milking for the control experiment.

Fig. 9. Shock: Six $\frac{1}{4}$-second pulses.

Though the shock is less in this experiment than in the previous one the inhibition is almost complete. It is possible that the invasion of flies on this occasion had some effect. The cow was evidently troubled by flies biting her legs and this would no doubt add to the effect of the

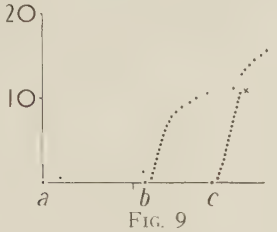


FIG. 9

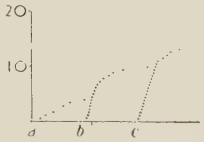


FIG. 10

shock. Again the second curve shows a marked curve towards the end which is absent from the control. The total amount of milk from the inhibited milking is less than from the control which yielded no second milk flow.

Fig. 10. Shock: Three $\frac{1}{4}$-second pulses.

The inhibition is less marked and a substantial amount of milk is obtained at the first milking. A curved second milk-flow curve is obtained. The control curve is the same in amount as the total for the two inhibited curves and is complete at the first milking. The effect is similar to that obtained with the 4 pulse shock with cow 261.

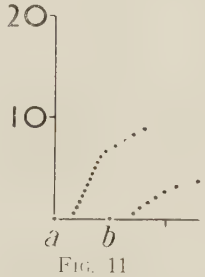


FIG. 11

Fig. 11. Shock: One $\frac{1}{4}$-second pulse.

The effect in this case is similar to that obtained from cow 261 when given a similar shock and is the sort of result that one would get in a badly run cow-shed where the cows are normally hand stripped. As another experiment was started the next day no control curve is available for this cow.

The accompanying table (Table III) summarizes the usual quantitative data from the curves given above. There is no marked tendency for less milk to be obtained as a result of the inhibited double milking procedure than from the control. It is quite evident that the cows produce a second flow of milk when milked the second time. All second milkings were preceded by a normal starting procedure. In fact all milkings were treated as if they were separate, complete operations. Disturbances which decrease the efficiency of the first let-down are obviously undesirable. The amount of milk obtained at the second milking following a mild disturbance or shock is of the order of that obtained by the farmer from the "strippy" cow. There is nothing in our results which is contrary to the experience of the practical farmer, and we feel

that the most likely explanation of the strippy cow is that she has not been trained to let-down her milk effectively at the start of the process, but has reverted to the primitive cow's tendency to give her milk "little and often". The main practical lesson to be learned from these experiments is that the starting of the cow is of great importance to fast, complete milking. The procedure adopted, namely, a thorough washing followed by the use of the strip cup, seems to be very satisfactory. We suggest that it should be treated as the minimum amount of stimulation for really efficient milking.

TABLE III. TABLE SUMMARIZING DATA FROM CURVES FOR INHIBITION EXPERIMENT

Fig.	Inhibited Milking.					Fig.	Control.				
	W.	T.	W/T.*	W/Tm	Total W.		W.	T.	W/T.	W/Tm	Total W.
Cow 261											
4 a	6·9	4·5	1·5	1·9		c	8·4	3·3	2·5	3·4	8·4
b	2·9	2·6	1·1	2·2	9·5	d	—	—	—	—	
6 a	2·8	6·7	0·6	1·0		c	8·4	4·6	1·8	3·2	
b	5·7	3·7	1·5	3·5	8·5	d	—	—	—	—	8·4
7 a	1·0	2·5	0·4	—		c	5·0	6·0	0·8	1·9	
b	4·8	3·5	1·4	2·9	5·8	d	1·3	4·7	0·3	0·5	6·3
Cow 262											
8 a	1·6	5·2	0·3	0·6		c	8·4	2·7	3·1	4·1	
b	5·9	3·3	1·8	4·1	7·5	d					8·4
9 a	0·4	5·6	—	—		c	8·4	3·1	2·7	4·6	
b	5·7	3·6	1·6	4·2	6·1	d					8·4
10 a	2·0	4·3	0·5	0·6		c	6·8	3·0	2·3	3·7	
b	4·8	2·7	1·8	4·5	6·8	d					6·8
11 a	4·8	4·0	1·2	2·6		c					
b	1·9	4·0	0·5	0·8	6·7						

* Rates are calculated to the end point of 0·5 lb./minute. Weights are totals for the 7 minute milking period.

The mechanism of inhibition is not clear from the above experiments. Either it could be the failure of the conditioned reflex as a result of the electric shock acting as an "extraneous stimulus" in the Pavlovian sense, or it could be of endocrine origin, i.e. a rise in the adrenalin level following the shock. The cows' reactions to the shock varied. Usually they stopped chewing the cud for a few minutes. Sometimes, however, despite the fact that the shock effectively inhibited the let-down of milk, the cud chewing continued normally. The writer has always found that an injection of enough adrenalin to inhibit milk ejection causes a cessation of cud chewing, hence there is some reason to suspect that the adrenalin inhibition of milk flow is not a necessary explanation.

The fourth series of experiments was an attempt to discover what effect the time of application of the inhibiting stimulus has on the milk-flow curve. Again the double milking procedure was adopted with seven-minute milking periods and 18 minutes between the two milkings. Both milkings were started normally. The stimulus used in all cases was a half-second pulse from the induction coil.

Cow 261 became quite nervous as a result of the shock experiments. She came to regard the wire connection with great suspicion and was easily upset by flies. In addition she developed sore teats which made milking somewhat painful. In the following series of experiments cow 261 was used.

(a) This was intended as a control recording for the experiment the next day. However, the cow was beaten to her bail by another. She was quite upset and produced the accompanying ejection curves (Fig. 12). The first milking was distinctly inhibited. The curves show that the inhibiting effect of the disturbance in the shed procedure was as great as quite a marked electric shock.

(b) The cow was given a shock one minute after the milk had started flowing. The effect was a marked inhibition of the first curve (Fig. 13). However, on the next day when a control recording was made a distinct degree of inhibition was evident. The cow had apparently become a "double milker" without the need for an inhibiting stimulus, as is shown by the control curves (Fig. 14).

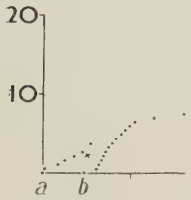


FIG. 12

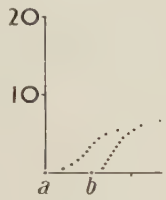


FIG. 13

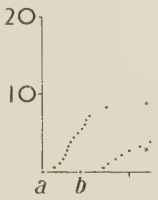


FIG. 14

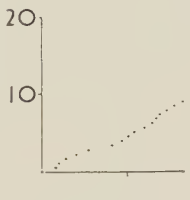


FIG. 15

(c) The cow was allowed to milk for a longer time than usual and no shock was applied. The curve (Fig. 15) has a double characteristic. It would appear that the cow had let-down her milk twice during the milking without additional stimulus. This is supported by the fact that following stimulation prior to second milking no milk was given in seven minutes.

(d) Throughout the experiment so far, flies had been a trouble in the shed. The milking recorded in Fig. 16 was accompanied by rain and an absence of flies. All of the cows were contented. The reaction of our experimental cow is marked. No second milk-flow curve was obtained. The increased volume of milk—probably a reflection of the end of the dry spell—is delivered in 3.3 minutes which is an improvement in rate.

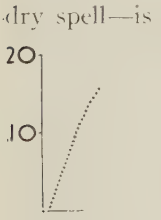


FIG. 16

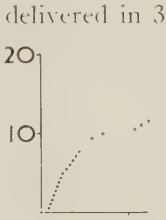


FIG. 17

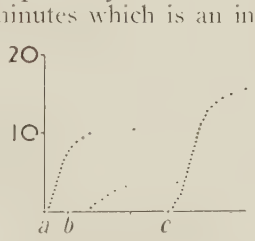


FIG. 18

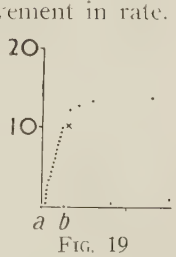


FIG. 19

(e) Following the normal ejection curve given the previous day, the cow was started in the usual way and a shock applied one minute after flow had started. Fig. 17 shows the curve. The first flow curve shows a second let-down component while there is no milk given to the second milking.

A similar series of experiments was carried out using cow 262.

(a) The cow became apprehensive on seeing the connecting wire. She promptly stopped chewing her cud. After a normal start a shock was applied one minute from the beginning of milk flow. Fig. 18 sets out the curves for this experiment and for the control recording the next day. A distinct second flow occurred. The control experiment

yielded no milk at the second milking. It is not possible to separate out the effects of the appearance of the wire from the actual shock in this case. In later experiments precautions were taken against the cow seeing the wire.

(b) This experiment was a repetition of the previous one but the cow did not see the wire. The first flow curve is hardly affected and only a small amount of milk, 0.4 lb., was obtained on second milking. The curves are shown in Fig. 19. This suggests that the inhibition of the previous experiment was due to the sight of the wire rather than the shock.

(c) This is a further trial of the procedure used in the two previous experiments. The same sort of result was obtained. (See Fig. 20). These experiments suggest that once the milk flow is under way it cannot be stopped by a marked stimulus. As there is some reason to believe that adrenalin would antagonize the action of the let-down hormone and that, therefore, a rise in its level would produce a slowing

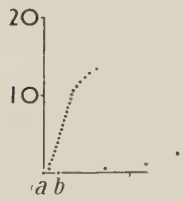


FIG. 20

FIG. 21

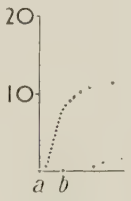


FIG. 22

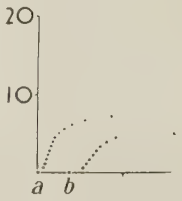


FIG. 23

up of milk flow (6), these experiments suggest that the inhibitory effects of electric shock prior to milking are mainly psychological and "break up" the conditioned reflex.

(d) In this experiment the shock was applied immediately the recording instrument indicated a flow of milk. As the curve shows (Fig. 21) there was no measurable effect. No second flow curve was obtained.

(e) This is a repeat of the previous experiment. A slight inhibition, as indicated by the existence of a small second flow curve, was obtained. (Fig. 22.)

(f) The cow in this case was shocked before the cups went on and just after the normal first starting procedure. The curves in Fig. 23 show that a distinct inhibition had occurred.

The above experiments indicate that the inhibiting effect of an electric shock of the order of that applied may be due to the breaking of a conditioned reflex rather than to the production of a rise in adrenalin level causing an effect directly on the mammary musculature. When a shock was administered just after milk flow was established there was plenty of time for adrenalin to have an effect, but no change in the milk flow curve seemed to occur. On the other hand, when a shock is given prior to milking, the degree of inhibition corresponds to the level of the shock and follows automatically. A further possible explanation is that once the mammary musculature has been contracted by the pituitary hormone, a rise in the adrenalin concentration does not cause an immediate relaxation. This point is to be investigated later.

The fifth experiment of the present series was designed to ascertain the effects of a normal farmer's milking procedure on the cow 261 which had been subjected to the double milking procedures described above. This cow had developed sore teats by the time the experiment

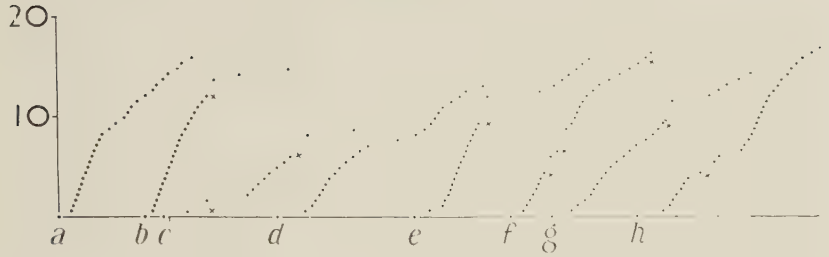


FIG. 24

started, so that she was sometimes a little distracted by the effect of the machine. However, the results are well worth recording as showing the effect of shed technique on the nature of the milk flow curve. The cow was started by a simple wash of the udder, the strip cup not being used. When milk flow fell to 0.5 lb. per minute the cups were pulled and the udder massaged so as to give a fair degree of stimulation to the cow.

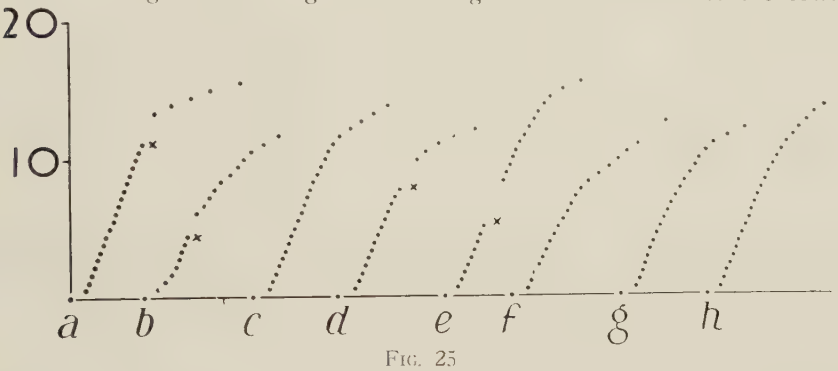


FIG. 25

Fig. 24 sets out the results in a series of milk ejection curves. The second curve is an exception in treatment as samples of milk were taken from the cow for a mastitis test and hence she was more than normally stimulated before the teat-cups were put on. A tendency to give a large amount of milk as machine strippings is evident. The last curve of the series typifies the cow which "holds her milk". About one minute after the beginning of the machine stripping procedure the flow increases rapidly and the cow milks out completely.

In view of the fact that another experiment seemed to cause a more marked let-down of milk following the washing of the teats with really hot water, this stimulus was tried with cow 261. On the day following the curve 24 h. this cow was started by washing with water at 60-65°c. and the strip-cup was again omitted. Fig. 25 sets out the milk ejection curves obtained for this otherwise normal milking procedure. It can be seen that the cow has become a normal milker again, the curves showing no tendency to break into two phases. In view of the fact that the cow was distracted by a sore teat throughout the experiment the results are surprising and stress the importance of a stimulating start.

Having trained the cow to give a reasonable ejection curve by using a hot water wash the author went back to a warm water washing procedure (temperature 30-40°c.). Fig. 26 sets out the curves obtained for part of the period. The first curve was obtained on the first day of the new treatment. The change apparently caused a reversion to the old double milking habit, making the previous period appear as a period of

inhibition of this characteristic. However, the subsequent curves are typical of the remainder of the warm water washing period. They are normal in all respects. Curve (c) is exceptionally high as the cow was in season and did not milk out at the morning's milking. It would appear that cow 261 is now a normal milker again after a series of somewhat unusual experiences.

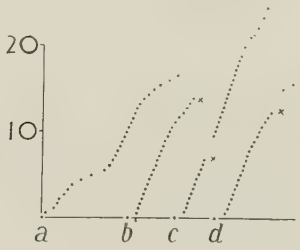


Fig. 26

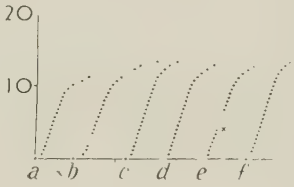
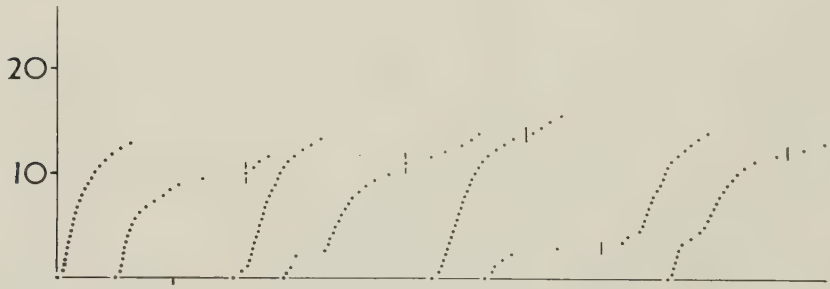


Fig. 27

Cow 262 was milked according to our normal shed routine. She immediately went back to her normal behaviour. Typical milk ejection curves for her during this final period are shown in Fig. 27.

The effects of electrical inhibition on two other cows are described in the following miscellaneous experiments:

Cow 4.—Fig. 28 shows this cow's normal milk ejection curve. Fig. 29 shows her response to 4 x $\frac{1}{4}$-second shocks one minute after the teat cups were applied. A slight inhibition of the first let-down is shown in this case. (The vertical lines crossing the curves are the points at which machine stripping was started.)



Figs. 28 - 34

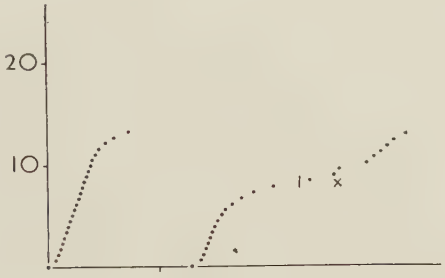
Fig. 30 is a normal milking curve recorded the day before Fig. 31 was recorded. This latter curve is the response evoked by giving the cow an electric shock (4 x $\frac{1}{4}$ second pulses) two minutes before milking instead of the normal starting procedure. There is a delayed start and some machine strippings are given. (This cow normally gives no machine strippings.)

Fig. 32 recorded the next day at a normal milking shows a small yield of machine strippings.

Fig. 33 shows the response to 8 x $\frac{1}{4}$ second pulses from the induction coil two minutes before milking. This has produced an effective inhibition. Only about a minute after machine stripping involving massage of the udder did a normal milk flow occur.

For three weeks following this experiment the cow gave "biphasic" ejection curves. These are typified by Fig. 34. Owing to the cow drying off at this stage it is not know how long the effect would have lasted.

Cow 212.—Fig. 35 shows her normal milk ejection curve. Fig. 36 shows her response to 4 x ¼-second pulses, two minutes before milking instead of the normal starting procedure. Normal machine stripping produced little effect, but a vigorous rub of the udder with a hot wet cloth produced a clear response shown on the curve about a minute after the point marked by the cross.



FIGS. 35 - 36

DISCUSSION

Of considerable interest is the fact that the cow can apparently be trained to eject two lots of hormone at a milking without extra stimulus. This is good evidence for the view that the secretion of the let-down hormone is a conditioned reflex. The reflex secretion of the milk let-down hormone from the neurohypophysis is of great theoretical interest. As the natural mechanism in the cow, or any other mammal, is intended to release milk from time to time to the young when the lactating gland is suckled, it is apparent that in the process of artificially increasing the milk producing ability of the cow, man has had also to develop an animal capable of letting down all of her daily yield in two lots. That the development of this phase of the evolution process is not complete is evident from the fact that there are in our herds to-day cows which will not milk out artificially to the machine but require hand stripping or vigorous machine stripping. Attention should be drawn to the fact that if the writer's view is correct, vigorous machine stripping produces the same result in the cow as hand stripping, namely, the secretion of more let-down hormone. Many farmers who say they do not strip are really machine strippers. It would be of great interest to examine the production figures of a large group of herds which do not have any treatment other than a brief pulling down on the teat cups after machine milking is complete. When a cow does not milk out normally to the machine two factors may be involved: either the starting stimulus is not adequate or the cow is physiologically incapable of secreting in one dose enough hormone to eject the milk properly. The cow which will not respond to training may be limited by her pituitary gland. This means that unless she is machine stripped she will decline in production when subjected to a strict non-stripping schedule. A field survey of the milk ejection characteristics of a large number of dairy cows would throw a lot of light on this problem.

The experiments described demonstrate that within a period of about twenty minutes or less a cow is able to respond at least twice to stimulation of her teats by releasing milk let-down hormone. If a milking has been incomplete this second stimulation results in the ejection of more milk and this "second milking" may vary from being simply "stripping" to having the volume and characteristics of a normal milk ejection curve. The second let-down has been shown by partially inhibiting the first milking by electric shock. Evidence for the possibility of a cow being conditioned to give a double milk ejection curve has been given. There is also evidence from some of the experiments for the view that the shock acts as a Pavlovian "extraneous stimulus" causing temporary partial inhibition of a conditioned reflex, rather than as a cause of a raised adrenalin level resulting in a "chemical inhibition" of the mammary musculature.

The writer is of the opinion that the "strippy" cow encountered in the field giving one-third or one-half of its milk to hand stripping following machine milking, does so because of an inadequate starting stimulus or an inadequate response by the posterior pituitary body, and the subsequent release of more hormone being dependent on a second stimulus. If this view is correct the aim of the milker must be to give the cow an adequate initial stimulus and to operate a regular shed routine which will firmly establish a strong conditioned reflex.

The fact that there is a relaxation of the mammary milk ejecting mechanism following "let-down," can be explained in two ways: either there is a "tiring" of the contractile elements or there is a dissipation of the hormone. The fact that further stimulation will produce a further ejection response indicates that while tiring may occur, it has less effect than the loss of hormone.

Reference has been made to the existence of an enzyme responsible for the destruction of pitocin in the blood of women (12). The increase in this enzyme as pregnancy advances will have a big effect on the milk ejection process and if it occurs in the cow will tend to cause her to dry off.

If Petersen's view that the milk ejection hormone is the oxytocic fraction of the whole posterior pituitary extract is accepted and examined in the light of present day knowledge of the chemistry of these substances some interesting problems arise.

Haterius and Ferguson (19) and Harris (2) have demonstrated that stimulation of the nerves supplying the posterior pituitary body releases an oxytocic substance. The latter worker shows that this response is more like that of pitocin (the oxytocic component of whole posterior pituitary extract) than pituitrin (the whole extract). Harris also demonstrates very clearly that stimulation of the neurohypophysis releases an anti-diuretic hormone, a component which on normal chemical separation (Kamm *et al.* [21]) goes with the pressor activity.

The question arises as to why the stimulation of the teats of the cow should cause a decrease in diuresis, a rise in blood pressure, an increase in motility of the uterus (if sensitive) and ejection of the milk if, as many workers hold, there is only one substance with multiple activities secreted by the neurohypophysis.

On the other hand, if there are, say, two hormones, one with oxytocic and milk ejecting properties and the other with pressor and anti-diuretic properties, why should it be possible to isolate from the posterior lobe a single protein with pressor, oxytocic and anti-diuretic activities?

(van Dyke *et al.* [22]). The situation may be explained by assuming the possibility suggested by van Dyke, that the whole protein (which is evidently unstable) can be caused to release a suitable active fragment under the influence of a specific enzyme. This still leaves the puzzle raised by the demonstration of the existence of an enzyme which increases one thousand-fold up to the termination of pregnancy and which is thus capable of destroying the oxytocic hormone at a very great rate just at the time when it is required if it is assumed that the enzyme really has an endocrine role at parturition.

A problem of the first importance in the elucidation of the milk ejection mechanism is the study of the "pitocinase" system (if any) in the cow. It will be evident that the efficient delivery of the milk of a cow at a milking will depend on the effectiveness of the reflex releasing the ejection hormone and on its rate of destruction in the blood, i.e. upon the concentration of pitocinase. The question of whether a cow can be efficiently milked out with only one "dose" of ejection hormone, i.e. whether she needs "stripping" or not, is also a function of this destruction rate. It is possible that an explanation of the behaviour of the cow which will not respond to a "non-stripping" regime will be found in terms of the ability of the posterior lobe of the pituitary gland to release enough hormone during a milking, and the rate of destruction of this hormone when released.

ACKNOWLEDGMENT

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NOTE ON THE FIGURES.

The vertical scale is marked in pounds of milk, the points on the graphs being 0.54 lb. apart. The horizontal time scale is marked at five minutes from the zero to indicate the scale.

Fig. 2.—Cow 161:

A.C.	first pair of quarters	milked.	
B.D.	second „	„	unstimulated.
E.G.	first „	„	
F.H.	second „	„	stimulated.
Cow 262:			
I.K.	first „	„	
J.L.	second „	„	unstimulated.
M.O.	first „	„	
N.P.	second „	„	stimulated.

Fig. 3A.—The milk ejection curves given by cow 261 when subjected to a double machine milking procedure. The second milking curves show small amounts which finally fall below 0.5 lb. and are not recorded.

Fig. 3B.—The milk ejection curves given by cow 262 when double machine milked. No second milking curve is given.

THE NUTRITIVE VALUE OF PAMPAS GRASS (*CORTADERIA SELLOANA*)

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Summary

(1) The digestibility of pampas grass has been measured in a series of 20 trials using dry, non-pregnant dairy cows. The resulting data have been used to assess the nutritive characteristics of the plant as a cattle fodder.

(2) Well recognized and popular "strains" of pampas grass showed no difference in nutritive value.

(3) Soil fertility showed no consistent relationship with variations in nutritive value of the herbage grown. Severe frosting appeared to reduce nutritive value.

(4) The removal of seed-heads during growth did not produce any effect upon nutritive value of the plant.

(5) The stage of growth of the plant showed a definite and consistent relation to nutritive value, material cut at three months of age being superior to six months' growth, and six months' growth superior to twelve months' growth. The fall in quality under annual cutting was sufficiently large to justify a recommendation that utilization should occur twice a year.

(6) Measurements of annual yield from three plantations over several years indicate that pampas may be expected to yield as much dry matter per acre as the same land under average pasture. The protein yield per acre was considerably lower than that available from pasture.

(7) The nutritive qualities of pampas have been compared with hay and silage and the general place of pampas in New Zealand cattle feeding discussed.

(8) The results indicate that pampas must be classified as a "hay" comparable with average quality pasture hay in nutritive value.

INTRODUCTION

WHILE pampas grass has not been cultivated extensively as a fodder crop in countries other than New Zealand, it has been in use here for more than twenty years. Its main function has been to supplement pasture in winter for dairy cattle and to a lesser extent for beef cattle. Although enjoying only limited popularity with farmers until the outbreak of the second world war, labour conditions, during the war and since, have led to increased plantings of, and interest in, the plant. This has resulted largely from the fact that once a plantation has been established, the labour required for maintenance and utilization is negligible. This is specially true relative to the labour demands of growing, harvesting, and feeding out, alternative types of supplementary fodder. Root and green feed arable crops need much labour in their production; hay and silage have heavy labour demands in harvesting; and all these types of fodder involve labour in their utilization. In contrast, pampas is readily "grazed off" by cattle when required.

While popular articles from Aston (1), Aston and Grimmett (2), and more recently from Lynch and Osborn (3), on the propagation, establishment and management of pampas have been published, factual information on the nutritive value of the plant is limited to a small number of chemical analyses of ash, dry matter, and protein, content of samples selected at random without reference to the stage of growth of the material analysed. Shorland and Brooker (4) have published a

limited amount of analytical data on material cut at approximately the six months' and twelve months' stage of growth. While the various carbohydrate fractions of their analyses are not strictly comparable with the crude fibre fraction commonly employed in metabolism studies, their data show the material to be relatively rich in carbohydrate and low in protein and ether extractable substances. Grimmett (5) has suggested that the high proportion of cellulose in the crude fibre might result in the latter being highly digestible. Various popular accounts of the usefulness of pampas grass, based on the experiences of growers, have been given from time to time in the agricultural press but only recently has any objective study of field experience been attempted (3).

In view of this lack of precise information on the nutritive characteristics of the fodder, investigations were commenced at Ruakura in 1943. A series of digestion trials were planned to provide not only a measure of the digestibility and starch equivalent value of pampas relative to other fodders, but also to study the influence of the various factors that had been claimed to affect the nutritive status of the plant. Thus, data were sought on the influence of strain, soil fertility, stage of growth, season, and of seed head removal. Twenty trials extending over four years have been completed. In addition, some data on yield of pampas on a per-acre basis have been collected.

Materials Used For Investigation

The pampas used was obtained from three separate plantations:

(*a*) *Ruakura:*

An eight-year-old plantation comprising plants of three origins, commonly described commercially as "strains." These are the three main strains available to farmers and in this paper have been designated Strain I, II, and III. The land comprised partly a well drained and consolidated peat-soil of relatively low fertility, and partly a peat-clay-loam transitional soil of medium fertility. Pasture species growing between the plants were brown top (*Agrostis tenuis*), Yorkshire fog (*Holcus lanatus*), and lotus major, on the peat area, with cocksfoot (*Dactylis glomerata*) dominant over these three species on the transitional area. The plantation was well established and cultivated, and at the commencement of the work carried twelve months' growth of herbage. The vigorous condition of the plants at the time of commencement of the work can be gauged from the relatively high dry-matter yields per acre during 1944 (Table VI).

(*b*) *Ngahinapouri Plantation:*

A three-year-old stand of Strain I pampas established in 1941 on a highly fertile clay-loam soil. This soil type on the remainder of the farm supports a first class ryegrass-white-clover dairy pasture and withstands drought conditions very well. Volunteer growth between plants consisted of ryegrass (*Lolium perenne*), white clover (*Trifolium repens*), and cocksfoot.

(*c*) *Rototuna Plantation:*

A three-year-old stand of Strain I pampas established in 1942 on a sandy-loam soil type of high fertility. This soil type carries a first class dairy pasture comparable with Ngahinapouri but it tends to dry out rather badly in dry weather. Volunteer species were similar to those

on Ngahinapouri. In both (*b*) and (*c*) the pampas plants used represented later selections of Strain I than those of the same strain employed in the Ruakura plantation.

EXPERIMENTAL METHOD

All digestibility trials were carried out with dry, non-pregnant dairy cows of the Jersey breed. In the first 14 trials, two cows per trial were employed; in the last six, three animals per trial were used to ensure greater accuracy. The pampas was cut every two days and chopped to ½ in. lengths to facilitate daily weighing, feeding, and sampling. Amounts fed varied from 14 lb. to 20 lb. green weight, the maximum the animals would consume under indoor conditions. This very low intake is a reflection of the poor palatability of the fodder. Fæces were collected by the "bag method" of Ballinger and Dunlop (6). In all trials a six-days pre-period followed by a ten-days collection period was employed. Analytical methods used in the treatment of feed and fæces samples are detailed in a paper (7) about to be published.

Results are reported mainly in terms of digestible organic matter, digestible protein, and starch equivalent values. Greatest weight has been given in the following discussion to variations in the digestible organic matter, a measure of gross nutrient value closely similar to the total digestible nutrient figure employed by American workers in comparisons of this type. Statistical examination of the data indicates that a difference of approximately 6 per cent in digestible organic matter is required for significance at the 5 per cent level.

To facilitate examination and discussion of results obtained, the data from comparable trials have been bulked where possible to provide a measure of specific factors under examination. Raw data covering each individual trial are shown in the Appendix.

RESULTS AND DISCUSSION

Influence of Strain

Three separate and strict comparisons are available between strains I and III. These are summarized in Table I. In considering these results it should be pointed out that Strain III represents relatively unselected material obtained from seed collected on a harbour reclamation area. In contrast, Strain I represents plants which have been specially selected for growth and palatability characteristics by its originator.

TABLE I. COMPARISON OF "STRAINS" OF PAMPAS

Trial No.	Season.	Stage of Growth.	Strain.	Per cent on Dry-Matter Basis.		
				D.O.M.	D.P.	S.E.
A	Winter	12 months	III	40·8	2·4	23·4
B	Winter	12 months	I	40·2	1·1	23·5
J	Winter	6 months	I	41·5	3·7	27·8
K	Winter	6 months	III	42·3	3·9	26·5
N	Summer	6 months	I	38·9	2·7	25·0
P	Summer	6 months	III	48·0	2·6	34·0

D.O.M. = digestible organic matter.
D.P. = digestible protein.
S.E. = starch equivalent.

In respect to material fed during the winter at either 6 or 12 months' stage of growth, it will be noted that no differences were recorded in either the digestible organic matter or in starch equivalent values. With six months old material fed in summer, Strain III showed significantly higher digestible organic matter and starch equivalent figures. When the results of these strictly comparable trials are considered in relation to the results from the 20 trials listed in the Appendix, it must be concluded that "strain" has not been an important factor affecting nutritive value in these experiments. In so far as palatability is concerned, observations throughout the period of the trials also showed no superiority of one strain over another. It will be noted from the Appendix that Strain II in the winter of 1946 (trials D and E) showed comparable figures with those in Table I. Unfortunately, strict comparison between all three strains in the same year at the same stage of growth is not possible from the data.

It might be objected that the above data for Strain I are obtained from a stand established in 1935, and that this represents a very early selection. It will be noted, however, that the results from the Rototuna plantation of Strain I, established in 1942, were no better than those from the earlier established plantations (trials G, M, and R). Even with the aid of any possible benefit of good fertility conditions as compared with low fertility, the later selections of Strain I pampas of 1941 and 1942 showed no superiority over Strain III of 1935 in trials K and M, and in trials P and Q. In the first pair the respective digestible organic matter contents were 42.3 per cent for Strain III grown on low fertility land and 40.0 per cent for Strain I on high fertility land at the same stage of growth and in the same season. In the second pair, the respective figures under comparable growth and climatic conditions were 48.0 per cent and 49.6 per cent respectively. That Strain I pampas has not altered substantially or reliably in nutritive value between the 1935 and 1942 selections is also indicated by a comparison of trials J and M, where the season, year, and stage of growth, are the same. The 1935 selections of Strain I (trial J) average 41.5 per cent digestible organic matter and the 1942 selection (trial M) from the same breeder, 40.4 per cent.

Influence of Soil Fertility

It has been suggested that soil fertility is a factor of major importance affecting the value of a pampas stand, and farmers have been advised to avoid using the plant on poor areas of the farm. The reasons advanced have been that good fertility conditions are essential for maximum yield of fodder of maximum quality. In so far as the second point is concerned, the digestibility trials carried out on material from Ruakura, Ngahinapouri, and Rototuna plantations provide a means of examining the possible effects of soil fertility. The relevant data are summarized in Table II. This work has yielded no data on the first point.

Series 1:

The trials of 1944 (N, P and Q) from low, medium, and high fertility soils respectively, suggested a direct association between fertility level and the nutritive value of the material grown. It will be noted, however, that the difference between the medium fertility and high fertility figure is not significant and the suggestion of a definite trend is due mainly to the low figure of the material from the low fertility

TABLE II. INFLUENCE OF SOIL FERTILITY ON NUTRITIVE VALUE

	Trial No.	Fertility Level.	Per cent. on Dry-Matter Basis.		
			D.O.M.	D.P.	S.E.
Series I (1944)					
6 months' growth summer	N	Low	38·9	2·7	25·0
Dry conditions	P	Medium	48·0	2·6	34·0
	Q	High	49·6	3·7	35·6
Series II (1944)					
6 months' growth winter	H	Low	48·6	4·4	34·5
Mild conditions, ample rain	L	High	48·2	2·8	33·5
Series III (1945)					
6 months' growth winter	J, K	Low	41·9	3·8	27·2
Severe conditions, low rain	M	High	40·4	2·3	26·4
Series IV (1944)					
12 months' growth	C	Low	35·6	1·5	20·4
Average conditions	F	High	47·7	2·0	32·5

area. This low value, however, is not confirmed by a subsequent trial in 1946 from the same area at the same stage of growth (trial O, Appendix). Here a digestible organic matter figure of 44.9 per cent on the low fertility area was recorded which compares favourably not only with that from the high fertility counterpart in 1944, but with the value of 46.6 per cent from trial R (Appendix) on the high fertility area in the summer of 1945.

Series 2:

Comparison of winter-grown material of six months' growth in 1944 under conditions favourable to growth showed no difference in the nutritive value of the material from soils widely differing in fertility (trials H and L), while the high figure from the low fertility area (trial H, Appendix) was confirmed by a similar value in 1946 from material from the same area (trial I, appendix).

Series 3:

Comparison of material of six months' growth under winter conditions of severe frosting similarly showed no differences associated with fertility levels (Series III), the values from both soil types being depressed below the figure normal for material of this age.

Series 4:

With material at 12-months' stage of growth, strict comparison is available for the year 1944 when a highly significant difference in favour of the high fertility area was recorded (trials C and F). The figure for the low fertility area, viz., 35.6 per cent, is the lowest ever recorded for pampas. Material from the same plantation the previous year gave an average value of 40.6 per cent (trials A and B) and in 1946 a value of 40.5 per cent (trials D and E) for digestible organic matter. In contrast, the figure for the high fertility area of 47.7 per cent is the highest ever recorded with 12 months' old material and is substantially in advance of that from the other high fertility plantation in the subsequent year of 43.1 per cent (trial G). It will be noted that protein values show no definite association with soil fertility.

While the trials carried out have not been organized ideally to provide strictly comparable measures of soil fertility effects, the data available at least suggests that these are by no means definite, but rather that fertility as such, bears little if any consistent relation to the quality of the material grown. The relation of soil fertility to total yield of herbage is referred to later in this paper.

Effect of Stage of Growth

Farmers' experience in the use of pampas has suggested that the stage of growth of the material affects its nutritive value to stock, this being reflected in a decrease in palatability as the plant ages and greater thrift of cattle on young, as compared with old, material. These reasons, along with the general considerations associated with the usefulness of any material as a supplementary food to pasture have led to recommendations of biennial, rather than annual, feeding-off. Fed twice a year, in winter and summer, the material is used to provide for the normal periods of grass shortage.

Accordingly, data have been sought on the nutritive value of 6 months' and 12 months' old material. For comparative purposes the value of three months' old growth has also been investigated, although it is recognized that grazing at this stage is hardly likely to fit the farm use of pampas under practical conditions. This is specially so since three months' grazing tends to kill out the stand. Results are summarized in Table III. In this table mean results for trials at the different stages of growth have been calculated. In each series some differences in strain and plantation origin (soil fertility) exist, but since these have been shown above to have little or no effect, this bulking is considered justifiable.

Table III. Influence of Stage of Growth on Nutritive Value

Series.	Trials.	No. of Trials.	Per cent on Dry Matter Basis.			
			D.O.M.	D.P.	S.E.	Range in D.O.M.
3 months	S-T	2	52·6	7·2	39·9	50-55
6 ,, (summer)	N-R	5	45·6	3·0	31·5	39-50
6 ,, (winter)	H-M	6	45·2	3·7	30·8	40-50
12 ,, (winter)	A-G	7	41·2	2·0	24·7	36-48

Highest digestible organic matter and starch equivalent values are recorded for the two trials involving material cut at the three months' stage of growth. At this time a value of 52.6 per cent for digestible organic matter and a starch equivalent figure of 39.9 per cent on a dry matter basis has shown pampas to have the nutritive characteristics of a good quality hay. The digestible protein content is also relatively high and more than twice as good as at other stages. As mentioned above, however, material at this stage of growth is of little practical interest.

At the six months' stage of growth both in summer and in winter a digestible organic matter value of approximately 46 per cent was recorded, with a starch equivalent of approximately 32 per cent. Although substantially lower in quality than the three months' old material, these figures for six months' growth are still at a very useful level.

At the 12-months' stage of growth, however, the mean digestible organic matter figure recorded was 41.2 per cent with a starch equiva-

lent value of only 24.7 per cent. On this basis the fall in quality has been to a level where the nutritive value of the resultant material has reached the poor hay class.

While these mean values are useful as general guides, some significance should also be attached to the range in nutritive value at the three stages of growth. It will be noted that at the six months' stage, the digestible organic matter of the best quality material closely approached the mean figure of the three months' material. Similarly, even with the 12-months' old material, one trial showed a relatively high value of 48 per cent. Viewing the data as a whole, however, it is clear that not only does stage of growth materially influence the nutritive characteristics of the material grown, but that the general field recommendation of biennial grazing appears to be essentially sound on qualitative or nutritional grounds. Material at the six-months' stage has still a high food value, considering the class of fodder involved and the use to which it is likely to be put. It should also be noted that younger material appeared to be more palatable to the animals used in these trials. Three months' old material presented workers with little difficulty in persuading animals to eat it, whilst six-months' old material was accepted more readily than the older 12-months' herbage.

Influence of Season

From Table I, II, and III it is possible to make comparisons between summer and winter grown material. Except for the fodder grown in the winter of 1945, the winter herbage was of comparable quality with summer material. That the climatic conditions operating can influence the value of material grown is clear from a comparison of six months' growth in the mild winter of 1944 with six months' herbage of the very severe winter of 1945. The digestible organic matter and starch equivalent values were substantially lower under the poor growth and severe frosting conditions operating. (See Table II.)

In this latter winter a succession of severe frosts ranging from 10°F. to 19°F. and averaging 13°F. occurred for a month prior to the commencement of the trials. The effects of frosting on the herbage were clearly visible. General field observations at Ruakura have indicated that such results are fairly typical of cold winter conditions.

Influence of Seed-Head Removal

Field propaganda associated with the sale of pampas to farmers has laid considerable stress upon the importance of seed head removal as a means of maintaining the high nutritional value of the plant. The influence of seed head removal—the heads being removed as they appeared—has been tested under digestibility trial conditions with the results summarized in Table IV, where it will be noted that no differences

TABLE IV. INFLUENCE OF SEED HEAD REMOVAL
(12 months' growth)

Treatment.	Trial Number.	Per cent on Dry-Matter Basis.		
		D.O.M.	D.P.	S.E.
With seed heads	D	41·1	2·4	24·6
With heads removed	E	39·9	2·4	23·1

were recorded in materials fed at the twelve-months' stage of growth. No trials at the six-months' stage were carried out since these were not considered worthwhile in view of the negative results with older herbage and since it is logical to expect larger influences of such a practice with older material should these exist.

It will be noted from Table VI that the removal of seed heads was associated with a greater total yield of herbage in the one year when records were obtained.

The General Nutritive Value of Pampas

It seems important to comment on the general nutritive characteristics of the material relative to alternative feeds which it is likely to replace. The usefulness of pampas under New Zealand conditions is tied to its potential value in replacing hay and/or grass silage as supplementary feeds for cattle. In Table V average values obtained for hay and silage in New Zealand are contrasted with those obtained for pampas in this series of trials.

Three types of hay are available for comparison: "average" quality pasture hay, good quality lucerne hay, and very good quality subterranean clover hay. It will be noted that in so far as digestible organic matter, digestible protein content, and starch equivalent values, are concerned, the higher quality pampas series compares quite favourably with the data for average quality hay. The poorer quality pampas series, however, falls considerably below average hay in nutritive value.

Relative to the "good" and "very good" leguminous hays, even the high quality pampas is substantially inferior. This is specially noticeable in digestible protein content, where lucerne hay is more than four times as high and clover hay more than twice as high as the best pampas.

Since very little lucerne and sub-clover hay is made in New Zealand, and since it is likely that even the "average" quality Ruakura hay is better than the average pasture hay saved in the field, these studies would indicate that in broad general terms, pampas has similar nutritive characteristics to the hay of the New Zealand farmer. The close similarity in the two types of fodder might be noted, the only major difference being in dry-matter content which is almost sufficiently low in pampas to rate this plant as a succulent type of feed. In so far as its nutritive value is concerned, however, pampas undoubtedly must be classified as a hay.

Relative to average silage it will be noted that even the higher quality pampas is substantially inferior in its nutritive qualities. This comparison is even more in favour of silage if it is made between the best pampas and good quality silage, superiority then being of the order of 23 per cent in starch equivalent, 17.5 per cent in digestible organic matter, and even more important, 14.1 per cent in digestible protein content. This makes good quality grass silage more than one and two-thirds times as good on a starch equivalent basis as high quality pampas.

Essentially therefore, pampas should be regarded as a fodder crop capable of replacing hay rather than silage in cattle feeding. On no grounds—either those of chemical analysis, digestible organic matter, starch equivalent, or especially digestible protein content—can it be regarded as a satisfactory milk producing fodder.

Table V. Comparison of Pampas with Hay and Silage

Type of Fodder.	Chemical Composition and Digestibility Coefficients. (Per cent dry-matter basis)						Nutritive Value. (Per cent dry-matter basis)		
	D.M.	O.M.	Protein.	Ether Extract.	Crude Fibre.	Nitrogen free Extract.	D.O.M.	S.E.	D.P.
Low quality pampas (10 trials)	32·5	91·6	5·8	1·7	34·9	49·2			
digestibility coefficients		44·1	40·7	37·8	45·1	43·8	40·4	24·6	2·4
Higher quality pampas (8 trials)	31·0	91·7	6·2	2·1	34·2	49·2			
digestibility coefficients		52·3	51·9	50·5	53·8	51·4	48·0	33·7	3·2
Average quality pasture hay (3 trials)	86·0	92·4	8·4	2·0	33 3	48·7			
digestibility coefficients		55·5	51·5	48·2	57·7	54·9	51·2	32·6	4·3
*Good quality lucerne hay (3 trials)	86·3	91·0	19·2	2·0	30·3	39·5			
digestibility coefficients		63·7	74·2	39·7	45·4	73·4	58·0	40·4	14·2
*Very good quality subterranean clover hay (4 trials)	84·2	92·3	12·9	1·6	28·9	48·7			
digestibility coefficients		69·4	60·3	30·2	67·6	73·0	64·1	47·1	7·8
Average quality grass silage (8 trials)	19·5	90·5	11·6	4·3	35·8	38·8			
digestibility coefficients		66·7	43·6	50·8	78·9	63·9	60·4	49·1	5·0
†Good quality grass silage (3 trials)	—	84·8	23·6	9·4	24·4	27·4			
digestibility coefficients		77·3	73·5	74·2	87·6	70·7	65·5	56·6	17·3

* Lancaster, R. J. (1943): *N.Z. J. Sci. and Tech., 25, (Sec. A)*, 131-51, and Bartrum M. P. (Unpublished).
† Sears, P. D., Sill, F. B., and Newbold, R. P. (1942): *N.Z. J. Sci. and Tech., 24, (Sec. A)*, 91-5.

Yields of Pampas

No discussion of the nutritive value of a fodder plant is complete without reference to the yield of nutrients that may be expected. While these studies have been concerned primarily with questions of quality of nutrients, the opportunity was taken to secure some data on yield under the conditions operating.

The yield per plant of all the pampas plants cut in the various digestibility trials was recorded. Per acre yields of dry matter were then estimated on a basis of 1,000 plants per acre which was the planting rate in the plantations under study. Lynch and Osborn (3) report a planting rate of 750-1,200 plants per acre from their field survey.

TABLE VI. PER ACRE YIELDS OF PAMPAS GRASS

Date of Cutting.	Period of Growth. (months)	Pampas Strain.	Location of Plantation.	Soil Fertility.	Green material tons/ac.	Dry matter lb./ac.	Dry matter lb./ac./yr.
Feb. 1944	6	III	Ruakura	L.F.	8·2	6,250	
Jan 1944	6	I	,,	L.F.	11·0	7,500	
Jun. 1944	6	I	,,	L.F.	9·1	5,950	13,450
Jan. 1944	6	I	Ngahinapouri	H.F.	4·9	3,500	
Jun. 1944	6	I	,,	H.F.	4·2	2,700	6,200
Jan. 1945	6	I	Rototuna	H.F.	5·0	3,400	
Jun. 1945	6	I	,,	H.F.	3·1	1,950	5,350
Jul. 1945	6	III	Ruakura	L.F.	6·4	4,400	—
Jul. 1945	6	I	,,	L.F.	4·9	3,450	—
Feb. 1946	6	I	,,	L.F.	4·7	3,500	
Jul. 1946	6	I	,,	L.F.	3·0	1,950	5,450
Jun. 1944	12	I	Ruakura	L.F.	11·2		8,200
Jun. 1944	12	I	Ngahinapouri	H.F.	6·5		4,700
Jun. 1945	12	I	Rototuna	H.F.	6·6		4,900
*Aug 1946	12	II	Ruakura	L.F.	9·4		7,350
†Aug 1946	12	II	,,	L.F.	10·9		8,500

Brackets indicate consecutive 6 monthly cuttings.
* With seed heads.
† Without seed heads.

In most cases, the Ruakura plantation yielded more fodder than the plantations on better land. This was probably due to the greater age of the Ruakura stand (established eight years) where individual plants were much larger than those in the younger Ngahinapouri-Rototuna plantations (established three years). For this reason it is not possible to assess the effect of soil fertility on yield.

It is also evident that the six-months' winter yields were considerably lower than the previous summer yields from the same area. The lower yields of dry matter for the six-months' material of the 1946 Ruakura trials as compared with those of earlier years are probably the results of continual cutting. Prior to 1943, the Ruakura plantation had been grazed only leniently in winter under twelve-months-growth conditions. On these data, the yields that might be expected under twelve months' grazing conditions are of the order of 8000 lb. dry matter per acre from old established plantations and 5000 lb. from young plantations. These compare favourably with the dry matter production per acre of 10,000-13,000 lb. recorded from "top quality" pastures, by Sears and Newbold (8), and of 8,000-10,000 lb. obtained from "good quality" pastures by Hudson and Doak (9) and Elliott and Lynch (10). It is unlikely, however, that the average yield from grassland exceeds 6000 lb. to 8000 lb.

annually. These yields for pampas do not take into account the yield of fodder from the pasture grasses growing between the rows. It will also be noted that the highest yield recorded of 13,000 lb. in a plantation that had been grazed only leniently for some years, compares well with the best recorded pasture yields.

While the data are meagre, it seems probable that under reasonable conditions of soil and climate, a mature pampas stand regularly grazed could produce an amount of total fodder over the year comparable with that obtainable from average pasture under similar conditions. The quality of this material is of course much inferior to that available from grass. This is specially so in respect of protein yield. On a basis of 6000 lb. of dry matter per acre for grass, this will yield over 800 lb. of digestible protein per acre. A stand of pampas yielding 8000 lb. of dry matter will supply little more than 200 lb. of digestible protein per acre. This situation must be remembered in comparing relative yields of grass and pampas.

CONCLUSION

From these studies it is possible to form a more reliable judgment than has been possible hitherto as to the value of pampas to the New Zealand cattleman.

In the first place, it is quite clear that from a nutritive point of view, the fodder provided from pampas should be regarded essentially as possessing the characteristics of hay. Since hay finds its greatest usefulness during the winter period when it provides the greater part of the maintenance requirement of the dry pregnant cow, pampas could be used for this purpose both by the dairy farmer and by the hill country sheep farmer for cattle feeding. From limited intake studies at Ruakura it is clear that in conjunction with a small amount of pasture, sufficient pampas is consumed to provide for maintenance requirements. It is doubtful, however, whether a sole diet of pampas would be adequate, since it is unlikely that the cows can consume sufficient average quality material for their maintenance needs. This opinion is supported by limited-intake studies with dairy cows and by group feeding trials with beef cattle (steers) which were unable to maintain weight on a sole diet of pampas. This point, though worth emphasizing, should be largely of academic interest since in practice, it is unlikely that stock will be expected to maintain themselves on pampas alone. Considerable assistance is usually obtained from the grass herbage growing between the pampas plants, while the common method of providing a grass run-off for stock being wintered on pampas achieves a similar result. Wintering on pampas alone is unlikely if the above major recommendation—that the fodder should be regarded as a hay—is accepted by the farmer. For the same reasons, the provision of hay as a supplement to pampas—a practice frequently met in the field—is unsound on nutritional grounds.

It is equally clear from the studies that pampas cannot be considered suitable for milk production purposes. With a relatively low digestibility and a marked deficiency in protein, it is a bulky fodder, capable of supplying only a small part of the ration of a milking cow which needs supplementing with high quality pasture or concentrates in adequate amounts if milk yield is to be maintained. For this reason, the utilization of the summer six-months' growth presents a problem

As a "hay," it should be regarded merely as of maintenance value to the milking herd, and should be used for milking stock only under definite emergency conditions. Probably the best procedure is to utilize the summer six-months' grazing by feeding off to dry stock over twelve months of age. Even these animals should also be provided with a good grass run-off. Their growth requirements involve a heavy protein demand which pampas is incapable of providing.

In the second place, the total yield of nutrients available from the plant appears to be at a reasonably satisfactory level. An acre of land under pampas should yield at least as much fodder per annum as the average pasture, with the advantage that, for the special purposes for which it is grown, this fodder can be available for use during the normal periods of pasture shortage. At the same time, it must be remembered that a first class pasture under good management is likely to exceed the yields than can be expected from pampas, especially in the yield of digestible protein per annum.

In the third place, the production and utilization of the fodder gives it many advantages from a farm-management—labour point of view. These advantages might be claimed as off-setting to some degree the rather poor quality of the herbage and the poor yields during the early years of establishment. As a perennial crop its establishment is not difficult and its maintenance calls for little labour. Relative to hay, which involves considerable labour and cost in harvesting and feeding-out, its production and utilization incurs negligible labour demands and no capital or maintenance cost in equipment other than fencing. On the dairy farm, where labour supply is a problem as is almost invariably the case on the one- and two-man unit, the use of pampas for wintering cattle has undoubted claims for consideration in localities where it will grow. Similarly, on farms where contour makes the provision of hay difficult, pampas can be used as an alternative.

At the same time it must be pointed out that this study of pampas in no way suggests the plant is capable of eliminating hay-making on the dairy farm, but merely that it can be used for the same purpose as hay in winter. Hay is required by the dairy cow at other periods of the year when pampas is not available. Young stock such as calves and yearlings benefit in a similar manner from hay feeding over a large part of the year.

In addition, the making of hay is a well tried practice essential to efficient pasture control and utilization on the dairy farm, and considerably more experience and factual information than is available at present, is necessary before any farmer should consider the complete replacement of hay-making by the provision of pampas.

The general farm management aspects of pampas under New Zealand conditions have been recently summarized by Lynch and Osborn (3) on the basis of a field survey of factors associated with the establishment, maintenance, and utilization, of the plant.

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APPENDIX

DIGESTIBILITY TRIALS OF PAMPAS

Trial No.	Date.	Period of Growth (Mths.)	Strain.	Plantations.	Soil fertility.	Season.	Percentage Chemical Composition of Dry Matter.					D.O.M. per cent.	D.P. per cent.	S.E. per cent. (Wet)	S.E. per cent. (Dry)
							Ash.	Protein.	Ether extract.	Crude fibre.	Nitrogen free extract.				
A	1943	12	III	Ruakura	Low	W.	6·9	5·3	0·7	35·0	52·1	40·8	2·4	7·9	23·4
B	1943	12	I	,,	,,	W.	7·4	3·9	1·1	34·9	52·8	40·2	1·1	8·2	23·5
C	1944	12	I	,,	,,	W.	7·4	4·9	1·8	34·4	51·5	35·6	1·5	6·7	20·4
D	1946	12	II	,,	,,	W.	8·7	5·8	1·8	35·6	48·1	41·1	2·4	8·6	24·6
E	1946	12	II	,,	,,	W.	9·0	6·1	1·3	35·6	48·0	39·9	2·4	8·0	23·1
F	1944	12	I	Ngahinapouri	High	W.	8·3	4·4	1·9	35·2	50·2	47·7	2·0	10·5	32·5
G	1945	12	I	Rototuna	,,	W.	7·8	4·8	2·1	36·2	49·1	43·1	1·9	8·4	25·4
H	1944	6	I	Ruakura	Low	W.	8·3	7·3	1·8	34·0	48·6	48·6	4·4	10·1	34·5
I	1946	6	I	,,	,,	W.	8·6	9·0	2·0	34·3	46·1	50·1	5·2	10·4	36·1
J	1945	6	I	,,	,,	W.	9·8	7·2	2·6	34·4	46·0	41·5	3·7	8·7	27·8
K	1945	6	III	,,	,,	W.	8·7	7·6	1·7	36·1	45·9	42·3	3·9	8·1	26·5
L	1944	6	I	Ngahinapouri	High	W.	7·8	5·3	1·6	35·4	49·8	48·2	2·8	9·5	33·5
M	1945	6	I	Rototuna	,,	W.	8·7	6·1	1·4	33·4	50·4	40·4	2·3	7·6	26·4
N	1944	6	I	Ruakura	Low	S.	9·2	6·4	2·0	33·8	48·7	38·9	2·7	7·6	25·0
O	1946	6	I	,,	,,	S.	10·2	5·6	2·5	32·6	49·1	44·9	2·5	10·5	31·7
P	1944	6	III	,,	Medium	S.	7·0	5·5	2·5	33·4	51·6	48·0	2·6	11·5	34·0
Q	1944	6	I	Ngahinapouri	High	S.	8·4	6·7	2·4	33·5	49·0	49·6	3·7	11·3	35·6
R	1945	6	I	Rototuna	,,	S.	7·9	6·1	1·7	34·9	49·5	46·6	3·2	9·6	31·3
S	1943	3	III	Ruakura	Low	Sp.	11·1	12·8	2·0	30·5	43·6	55·3	8·8	11·8	44·3
T	1944	3	III	,,	,,	Aut.	9·3	8·6	1·5	34·2	46·4	50·0	5·5	9·8	35·5

INTERNAL PARASITISM IN CANTERBURY SHEEP

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Summary

Observations covering six years' parasitological investigation on a lamb fattening flock are reported.

Ostertagia was the most common nematode but *Trichostrongylus* was the most pathogenic. *Haemonchus* was absent.

The level of infestation was generally low but reached its peak in lambs 4-6 months old. In only two years, when the summer was wetter than normal, did a favourable weight response follow drenching with phenothiazine.

Gross infestation of lambs on special feed crops, such as rape, lupins, chou-moellier or turnips did not normally occur. However, in a season of high summer rainfall, when clover undercover amongst the fattening feed was abundant, reinfestation of lambs was observed.

INTRODUCTION

As part of a comprehensive series of experiments conducted at the Kirwee Experimental Farm between 1940-7, embracing the feeding of sheep under Canterbury conditions upon pasture and various specially grown feeding-stuffs, observations were made upon the nature and extent of infestation of sheep by pathogenic species of nematodes. This was thought to be the more important because evidence had accumulated (1) during the years of sheep mortality that internal parasites played an important part in its causation.

A field survey, conducted during 1938-9, when losses in sheep were very high, had shown that the number of worms of the pathogenic species carried by unthrifty sheep frequently reached dangerous levels. This information was obtained from a series of total worm counts made upon unthrifty sheep killed on farms, and from sheep slaughtered at meat works.

It was found that the commonest worms in Canterbury were *Ostertagia* spp. (mainly *O. circumcincta*) and *Trichostrongylus* spp. (*T. colubriformis, T. vitrinus,* and *T. axei*) with *Cooperia* spp. much less frequent. *Haemonchus contortus* infestation was confined to a relatively narrow strip of country at the base of the main mountain range and the heavier land round Lake Ellesmere. In the spring and early summer, fairly high counts of *Nematodirus* spp. were sometimes encountered, while *Chabertia ovina* and *Oesophagostomum venulosum* were rarely found in numbers over fifty.

The largest number of deaths occurred in lambs just before and for some time after weaning, from December to April, and it was at this time that the highest worm counts were obtained.

The range of worm counts and the mean counts of the commonest species found during 1938 are set out in Table I.

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EXPERIMENTAL

The present paper is concerned with the parasitological aspects of a series of sheep-feeding experiments conducted at Kirwee in order to investigate the relationship between nutrition and the incidence of mortality in sheep. The results of the sheep-feeding experiments as a whole will be presented in a subsequent paper; in this paper the parasitological aspects are considered under the following conditions:—

(1) Winter feeding of ewes and subsequent feeding of both ewes and lambs until weaning.

(2) Summer fattening of lambs on specially grown feeds.

(3) Winter feeding of hoggets.

The experimental sheep comprised 10 groups of 20-30 animals grazing a variety of feeds. They were randomized on a body weight basis and half of each group was drenched with an anthelmintic.

TABLE I. TOTAL WORM-COUNTS FROM UNTHRIFTY LAMBS KILLED IN THE FIELD IN CANTERBURY, FEBRUARY TO JUNE, 1938

Genera.	No. of specimens.	No. Infested.	Maximum Count.	Mean No. of worms present.	
				Infested Lambs.	All Lambs.
H. *contortus*	111	26	13,650	1,632	382
Ostertagia spp.	111	102	37,980	5,287	4,858
Trichostongylus spp.	111	108	81,540	13,622	13,253
Cooperia app.	111	73	24,450	4,478	2,945

The general method was to take faecal samples for egg-counts at random from an equal number of drenched and undrenched sheep in each group at the beginning of an experiment and to sample the same sheep at intervals during its course, a final sample being taken on the day the experiment was completed. Limited laboratory facilities and staff made it impossible to deal with more than 60-80 samples at a time during the progress of an experiment, which sometimes represented five or less drenched and undrenched sheep from each feed treatment group. The authors realize that these numbers are quite inadequate to demonstrate statistical differences between feed treatment groups but consider that lumped together they are sufficient to demonstrate seasonal trends and the overall effect of drenching. For the purposes of this paper, therefore, feed treatment differences have been ignored, and counts from all sheep of the same anthelmintic treatments on each type of feed within an experiment have been grouped.

The Gordon-Whitlock (2) egg counting technique was used and the following correction factors for faecal consistency applied:—

P — pellets	original count	
SF — soft formed (pellet formation beginning) ...	,, ,,	x 4/3
S — soft (no formation, sticky)	,, ,,	x 2/1
VS — very soft (mushy - to - thick liquid)	,, ,,	x 3/1
D — diarrhoeic (liquid)	,, ,,	x 4/1

The above correction factors have been employed in an attempt to reduce the errors due to the dilution effect that occurs in faeces of low dry-matter content. A similar procedure is adopted by workers in the McMaster Animal Health Laboratory in Australia (3). British workers (4) have attempted to solve the same problem by the slightly different means of using varying weights of faeces depending on the consistency.

All egg-counts in this paper relate to the genera *Ostertagia* and *Trichostrongylus*. Both *Nematodirus* and *Strongyloides* have been ignored, H. *contortus* was never encountered in total worm-counts, while *Cooperia* and *Bunostomum* were so rare as to have little effect on the total worm egg-count.

The anthelmintic used was phenothiazine, except that, prior to this drug becoming available in autumn of 1941, a two per cent copper-sulphate/nicotine-sulphate solution was given at the appropriate dosage, i.e. 1 oz for weaned lambs, 1½ oz for hoggets, and 2 oz for ewes. On two occasions, viz. with winter hoggets in 1944 and fattening lambs in 1946, various dose levels of phenothiazine were tried. Otherwise, the dose rate has been based upon Gordon's suggested dosage of 0.6 g. per kilo of body-weight (5). Drenching was carried out at three-weekly intervals in the summer fattening experiments and at monthly intervals in all other experiments.

At the conclusion of the summer lamb-fattening experiments, most of, if not all, the lambs were sent to a local freezing works for slaughter and, on a number of occasions, the opportunity was taken to collect the gut contents from a number of lambs in order that total worm-counts could be made when the previous egg-count history was known. In this way, it was possible to obtain added information on numbers and species of worms present, and the correlation with the final egg-count made at the conclusion of the experiment.

Throughout the years, an attempt was always made to undertake total worm-counts on the occasional animal which died in any experiment provided it was discovered soon after death. These are not summarized here since they serve only to confirm statements previously made concerning species present.

RESULTS

1. Ewes:

The winter-feeding of ewes extended from the beginning of June to the end of August, when lambing commenced. Since it was necessary to judge the effect of winter treatment of the ewes by the subsequent behaviour of their lambs, the ewes were kept under observation until weaning which generally took place early in January of the following year.

A fairly extensive series of observations upon the ewes were made during the winter-feeding periods of 1940-4; in every year the level of worm infestation was consistently low. In 1940 and 1941 a slight rise in egg-counts did occur in the spring, but in the later years null faecal egg-counts were given by the majority of the ewes throughout the period of observation. Table II summarizes the results of egg-counts made on the experimental ewes from June to October 1940-4.

Throughout the five years that these trials were conducted, there was, neither before nor after lambing, any indication amongst the ewes of unthriftiness which could be attributed to serious worm infestation. It is not surprising, therefore, in view of the low level of infestation which appears to be the rule on the Canterbury plains from June to October, that there was no response to the administration of anthelmintics. Subsequent to tailing and castration in late September, interest of the authors was transferred to the lambs which were being reared

by these ewes. As it was found possible to obtain faecal samples from lambs in October at the age of six to eight weeks, observations on the ewes ceased from that date.

TABLE II. MEAN EGG-COUNTS OF EWES. 1940-44

Year.	Treatment.	No. of counts.	No. of eggs per gram of faeces.					Anthelmintic.
			Jun.	Jul.	Aug.	Sep.	Oct.	
1940	drenched	30	110	140	120	lambing	240	nicotine/
,,	control	30	130	250	230	lambing	615	bluestone
1941	drenched	30	125	80	150	120	270	nicotine/
,,	control	30	150	90	110	50	430	bluestone
*1942	—	80	110	60	40	90	410	Not drenched
1943	drenched	40	80	110	lambing	150	nil	phenothiazine
,,	control	40	80	150	lambing	140	nil	
1944	drenched	40	50	70	lambing	100	90	phenothiazine
,,	control	40	40	70	lambing	70	80	

* No drenching of ewes was done in 1942.

2. Unweaned Lambs:

This part of the experiment was conducted during the years 1940-5 from October to the time in January when weaning took place. Except in 1940, the procedure followed was to run all groups of ewes and lambs together after marking, on saved pasture which was usually the best available on the farm. Table III shows the mean monthly egg-counts on unweaned lambs from 1941-5.

TABLE III. MEAN EGG-COUNTS OF UNWEANED LAMBS. 1941-5

Year.	Treatment.	No. of counts.	No. of eggs per gram of faeces.				Anthelmintic.	Per cent. of lambs sold as fat.
			Oct.	Nov.	Dec.	Jan.		
1941–2	drenched	35	120	140	—	180	phenothiazine	30
	control	35	250	160	—	450		
*1942–3	—	80	740	540	1,260	1,820	no drenching done	nil
1943–4	drenched	38	160	620	350	400	phenothiazine	31
	control	39	150	530	500	970		
1944-5	drenched	40	130	670	250	460	phenothiazine	35
	control	39	100	670	240	730		
1945–6	—	56	370	810	380	120	no drenching done	70

* No drenching done in 1942.

This table does not include figures for 1940, since in that year the experimental design differed and the use of correction factors for faecal consistency had not been adopted. Table IV, however, gives the mean egg-count figures for 1940 and is included in order to demonstrate the apparent ineffectiveness of nicotine sulphate/copper-sulphate solution in reducing egg-counts in young lambs grazing under certain field conditions.

It can be seen from Table III that in only one season (1942-3) did egg-counts rise to levels where an adverse effect on weight-gains could be expected. Support for the belief that the high level of infestation was associated with unthriftiness in the lambs is given by the fact that in that year no lambs were fat enough at weaning to be fit for killing, whereas in 1945-6, for instance, when egg-counts were very low, 70 per cent of the lambs were marked by a fat-lamb buyer as being fit for slaughter. In the years 1941-2, 1943-4, 1944-5, when half the lambs were drenched with phenothiazine, no weight-differences occurred between treated and untreated animals. There was, however, a definite reduction in the egg-counts of drenched lambs as compared with control lambs; this was most marked during the last month of the experiment.

TABLE IV. MEAN (UNCORRECTED) EGG-COUNTS OF UNWEANED LAMBS. 1940

Group.	Feed.	No. of counts.	No. of eggs per gram of faeces.			
			Oct.	Nov.	Dec.	Jan.
1*	Sub-clover pasture	12	160	540	1,010	860
2	Green-feed oats until Nov. then pasture	12	0	270	360	550
4*	Italian rye-grass until Nov. then pasture	12	220	520	620	1,310
5	Sub-clover pasture	12	320	900	1,420	1,170

* Groups drenched at monthly intervals with ½ oz. 2 per cent. nicotine sulphate/copper sulphate solution.

The variation from year to year in the level of egg-counts prior to weaning is seen in Table III. This variation became more marked after weaning. An examination of local meteorological data indicates that such variation is closely associated with rainfall and temperature. As this variation is more pronounced in the case of weaned lambs, it will be discussed in the following section.

3. Weaned Lambs Grazed on Fattening Feeds:

In this series of lamb-fattening trials the following types of lambs were used: 1941, store Corriedale wether lambs from a North Canterbury breeding flock; 1942, store Corriedale wether lambs, bred on the farm; 1943-6, store Corriedale-Southdown cross lambs of mixed sex bred on the farm. The trials commenced in January and continued for eight to twelve weeks, according to the amount of feed available. Rape was used for fattening the newly weaned lambs, while for purpose of comparison sweet blue-lupin was tried from 1944 onwards. With both types of feed, set-grazing, weekly break-grazing, and set-grazing with a compulsory run-off to pasture overnight were included.

Table V summarizes the egg-counts and weight-gains per day of drenched and undrenched lambs from 1941-5. The weight-gains for all seasons have been calculated from three constant treatment groups in which the behaviour of the lambs was similar. Groups such as those having a run-off to pasture which depressed growth-rate have not been included. This is done in order to give a reliable comparison between years as well as between drenched and undrenched sheep in the same year.

Table VI summarizes total worm counts made when lambs were slaughtered at the end of an experiment.

The 1941 egg counts were not corrected for consistency but are included here as offering added confirmation of the observation that egg-count levels always fall as the experiment proceeds. The use of a consistency factor increases the overall mean egg-count figure from 30 per cent to 50 per cent, and, allowing for this, the 1941 figures do not approach dangerous levels.

TABLE V. MEAN EGG-COUNTS AND WEIGHT GAINS PER DAY OF LAMBS IN FATTENING EXPERIMENTS 1941-5

Year.	Feed.	Treatment.	No. of eggs found per gram of faeces.						Weight gain per day. (lb.)
1941	Dates of	sampling	3/2	17/2	26/2	11/3	21/3		
1941	Rape	drenched (BNS)	670	320	250	260	230		0·36
1941	Rape	control	980	640	480	350	320		0·33
1942	Dates of	sampling	2/2	16/2	4/3	20/3	30/3		
1942	Rape	drenched(P)	1,300	380	200	100	110		0·37
1942	Rape	control	1,290	1,580	860	740	590		0·39
1943	Dates of	sampling	26/1	9/2	22/2	5/3	23/3	5/4	
1943	Rape	drenched(P)	3,660	2,840	2,040	1,250	870	650	0·22
1943	Rape	control	3,570	3,720	2,780	1,860	1,790	1,460	0·15
1944	Dates of	sampling	11/1	31/1	14/2	28/2	13/3	20/3	
1944	Rape	drenched(P)	1,270	550	190	100	100	90	0·28
1944	Rape	control	1,140	910	670	490	350	350	0·27
1944	lupin	drenched(P)	810	250	140	40	40	40	0·30
1944	lupin	control	970	800	450	500	230	220	0·29
1945	Dates of	sampling	1/2	15/2	1/3	12/3	5/4	23/4	
1945	Rape	drenched(P)	1,670	2,310	930	1,310	650	570	0·28
1945	Rape	control	1,340	4,060	2,290	2,620	2,040	1,310	0·24
1945	lupin	drenched(P)	1,560	1,020	590	880	560	340	0·29
1945	lupin	control	1,810	2,550	1,920	2,880	1,910	670	0·24

BNS = Bluestone/Nicotine sulphate
P = phenothiazine

TABLE VI. MEAN TOTAL WORM-COUNTS IN LAMBS 1943-5

Year.	Feed.	Treatment.	No.	Abomasum.		Small Intestine.	
				Ostertagia.	*T. axei.*	*Trichostrongylus.*	*Nematodirus.*
1943	Rape	Drenched	6	nil	100	1,250	280
	Rape	Control	6	850	230	3,780	880
1944	Rape	Drenched	3	350	nil	520	430
	Rape	Control	3	1,000	150	420	1,480
	Lupin	Drenched	3	560	nil	200	430
	Lupin	Control	3	620	50	800	600
1945	Rape	Drenched	10	440	nil	2,940	140
	Rape	Control	8	1,060	nil	2,510	110
	Lupin	Drenched	5	330	nil	5,420	470
	Lupin	Control	6	700	820	4,300	nil

In 1946 an entirely different drenching programme was carried out. It included single and repeated doses of 20 g. and 40 g. of phenothiazine, but as the mean initial infestation was so low in that year, viz. 240 eggs per gram, no differences could be detected, and the figures have not been included in Table V.

It will be seen from Table V that the level of worm-infestation was considerably higher in 1943 and 1945 than in other years, and it is on these two occasions that drenching had a beneficial effect on live-weight gains. The better growth made by the drenched sheep on both occasions was significant at the one per cent level over the whole experiment.

The mean levels of worm-infestation, in all the lamb-fattening trials, as judged by faecal egg-counts in the undrenched lambs, are shown in Fig. 1. These results suggest that two thousand eggs per gram of faeces (corrected for consistency) is the critical level above which drenching is likely to be effective in areas where *H. contortus* is not present.

Although these weight-gain differences due to drenching are statistically significant they represent a total bodyweight-gain of only 6 lb. in 1943 and 4 lb. in 1945 or a dressed-carcase-weight gain of 3 lb. and 2 lb. respectively. As the prevailing export price of grade fat-lamb at the time was ten pence per lb. such an increase in weight would barely pay for the phenothiazine and labour involved in the programme of three-weekly drenching.

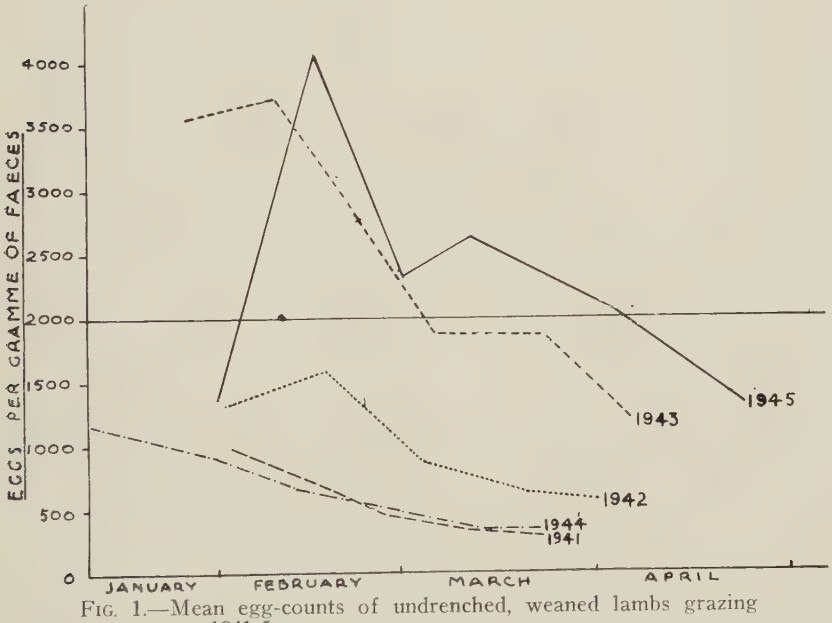

FIG. 1.—Mean egg-counts of undrenched, weaned lambs grazing on rape. 1941-5.

It might have been expected that the lambs given a run off to pasture at night would have been exposed to greater chances of re-infestation and consequently to have maintained a higher worm burden than those kept continuously upon feed. That this was not so is shown in Fig. 2 where, taking the two extreme years, viz. 1944 and 1945,

mean egg-count levels of lambs in run-off groups are compared with those o fthe continuous or set-grazing groups. Both Figs. 1 and 2 indicate that, apart from 1945, there is a steady fall in the egg-count level of the undrenched as well as the drenched lambs throughout each experiment. This is undoubtedly due to a combination of factors amongst which lack of re-infestation on the rape or sweet-blue-lupins and the development of an immunity are the most important.

Repeated attempts were made in the first two years of these experiments to isolate infected nematode larvae from rape. A modified Baermann apparatus was used whereby a considerable bulk of rape could be examined. A straight-sided circular metal container of three gallon capacity, the lower part of which tapered to a tap, was filled with water. Suspended in it was a 1/16-in. mesh wire basket containing 2-3 lb. of rape. This was agitated mechanically with an eccentric motion until the rape was washed clean. The debris was allowed to settle for 24 hours, drained off at the tap, and examined under a dissecting microscope. This method gave 50 per cent to 60 per cent recovery with artificially infested rape.

It was not possible to recover the infective larvæ from samples of rape in the paddocks where the lambs were grazed. This indicates that the infestation of the rape itself by the third stage larvæ is of a low order, if indeed it occurs at all.

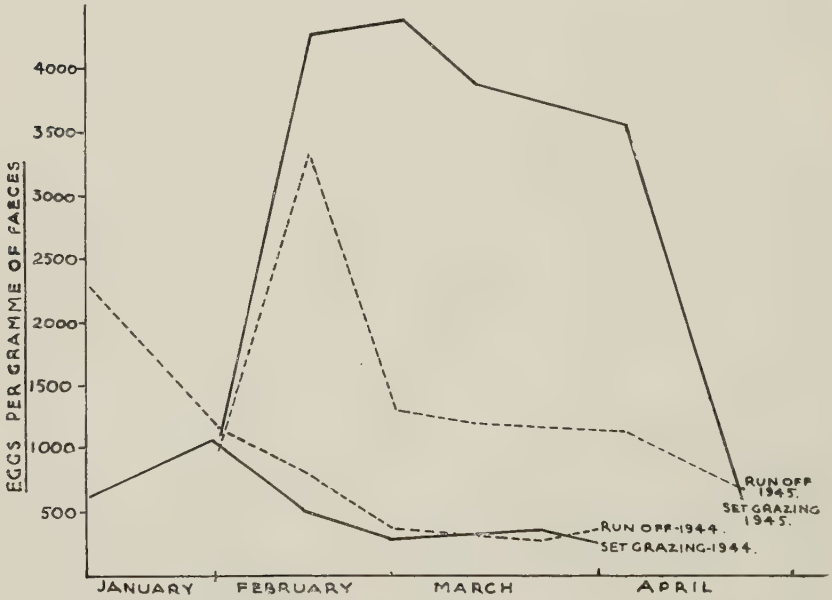

FIG. 2.—Mean egg-counts of sets grazed and night run-off groups of lambs on rape. 1944 and 1945.

Nevertheless, evidence that re-infestation of lambs continuously grazing a specially grown summer-fattening feed such as rape can occasionally occur, was given in 1945, when, owing to the prolific growth of the feed, 150 lambs (five experimental groups of 30 lambs) grazed one area of six acres from 2 February to 12 March, a period of 38 days, whereas in no other year did lambs graze any one area for a longer period than 21 days. Table V indicates that the reinfestation took place during the last fortnight of this period. Evidence was

obtained that the reinfestation arose from the grazing of self-sown subterranean clover undergrowth which, due to the unusually wet season, was abundant. The small and variable amount of weed growth—sorrel, spurry, trefoil, volunteer white and subterranean clovers—which composes the undercover in most summer feed crops, usually dies off in the dry summer weather or is trampled out by the grazing lambs. That the undercover was responsible for the reinfestation of the lambs in 1945 is shown by two observations.

(1) Using the Baermann funnel technique, mixed *Ostertagia* and *Trichostrongylus* third-stage larvæ were recovered at the concentration of 1,040 larvæ per lb. of green herbage from a sample of undergrowth collected from the area of rape concerned, immediately after the lambs had been taken off.

(2) Re-infestation also occurred in the lambs grazing upon sweet-blue-lupins. With its exposed woody base this tall plant, which lambs habitually graze from the top downwards, appeared singularly well-adapted to prevent contamination by third-stage infective nematode larvæ.

It is interesting to note that, in spite of the high level of initial infestation of lambs on both rape and sweet-blue-lupins, as well as the degree of re-infestation in some sheep on this occasion, there was the usual marked drop in faecal egg-counts of both drenched and undrenched lambs by the time the experiment was completed. It is this consistent falling off of egg-counts which is the salient feature of all the lamb-fattening trials at Kirwee, and, because of it, the total worm-counts made at slaughter show little difference between drenched and undrenched lambs. Drenching, in other words, only serves to accelerate this normal process and it is therefore hard to assess its usefulness.

It is generally recognized that weather conditions, especially the interaction between rainfall and temperature, are closely associated with the year-to-year variation in worm infestation, a variation which in Canterbury reaches its peak a few weeks after weaning. Although in all years the same lambs were not used in the feeding experiments before and after weaning, they were, in the " bad " seasons concerned, all reared on the farm under similar conditions. It is reasonable therefore to conclude that the high level of egg-counts reached in February (Fig. 1) was an extension of the rises which occurred before weaning (Table II). Therefore the weather in November and December would appear to play an important part in the development of infestation. It is perhaps advisable at this point to describe briefly the type of conditions which usually prevail at Kirwee during spring and early summer.

There is generally a spectacular growth of grass and clover during September and October which persists until the advent of dry weather conditions with accompanying warm north-west winds during late November or December. Because of the very porous nature of the subsoil, the countryside dries up very rapidly, clovers wither, the grasses go quickly to seed, and the only palatable feed available is specially grown crops. Such conditions prevailed in seasons when internal worm parasites were not a problem, and an examination of rainfall records kept at Kirwee shows that in each instance there was a dry spell of at least four weeks in November-December, during which less than 0.6 in. of rain fell. In the seasons 1942-3 and the 1944-5,

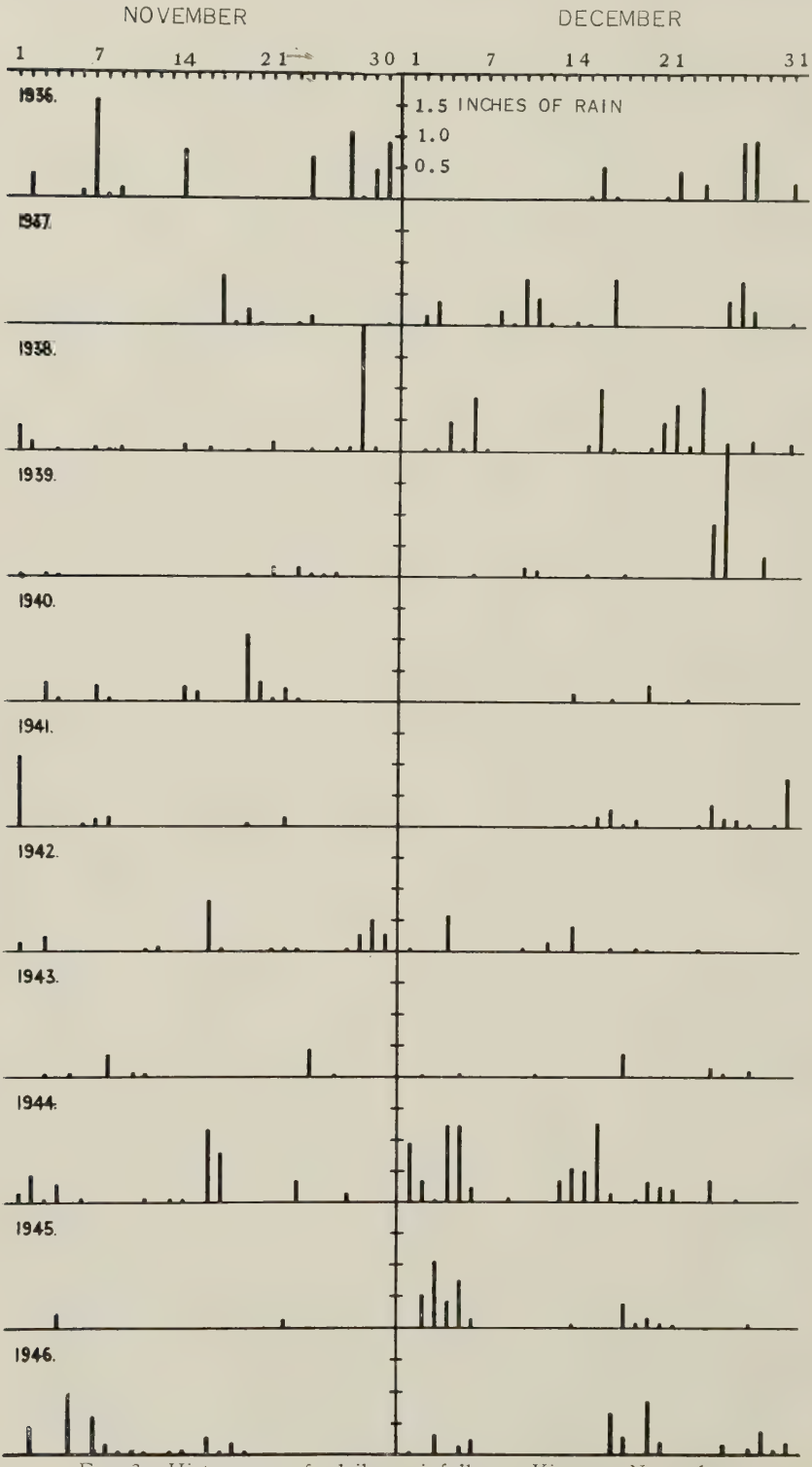

FIG. 3.—Histogram of daily rainfall at Kirwee, November-December 1936-46, showing the "wet" seasons of 1936-8, 1942, and 1946.

however, when parasitism did reach dangerous proportions and green growth continued until weaning or even, as in 1945, until March, the records show no such prolonged dry spells. (See Fig. 3.)

An interesting exception occurred in 1946. A wet early summer was again experienced, and although no planned parasitological experiments were being conducted, routine egg-count checks on lambs before and after weaning showed mean figures of eggs per gram to be as low as 400 in December and 180 in February. Experience in past seasons would have suggested that high egg-counts were to have been expected. The authors believe that the reason for this not occurring was the abnormally low temperatures experienced during November, which prevented the development of the free-living stages. For the three wet years the mean monthly maximum and minimum temperatures at Lincoln College, only eighteen miles distant from Kirwee, are shown in Table VII.

From these facts it would appear that the interaction of rainfall distribution and temperature in November and December play a decisive part in determining the subsequent worm-infestation of the lambs.

TABLE VII. MEAN MONTHLY MAXIMUM AND MINIMUM TEMPERATURES AT LINCOLN COLLEGE

	1946.		1944.		1942.		Station Average.	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
October	59·7	39·1	62·0	41·1	63·7	45·1	*63·1*	*43·7*
November	59·8	38·8	64·9	42·9	66·7	46·6	*66·2*	*46·2*
December	65·6	46·3	65·2	46·6	68·7	46·8	*69·6*	*49·3*

NOTE: Not only was November, 1946, abnormally cold as judged by mean temperatures, but 14 ground frosts were recorded, in contrast to the three or four generally occurring during this month.

4. Winter-Fed Hoggets:

The observations upon hoggets extended over approximately four months from May to September during the years 1941-5 and formed part of the general study of sheep management and feeding practices.

Table VIII gives the mean faecal egg-count and weight-gain per day of drenched and undrenched sheep. The hoggets used in the 1941-44 trials were ewe Corriedales bred on the farm and being kept for flock replacements whereas those used in 1945 were half-bred wethers purchased as backward store lambs in the previous March. Thus in neither case can their initial egg-counts be closely related to the final egg-counts of the lamb fattening trials.

Although, for reasons mentioned earlier, egg-counts are not shown under treatment headings, in this instance weight gains are shown under high and low planes of nutrition, the former being calculated from hoggets on specially grown winter feeds, turnips, chou moellier and Italian rye-grass, the latter from a group maintained each year on poor permanent pasture typical of that found in much of the light land of Canterbury. From this it can be seen that weight differences due to drenching were of a similar order on both planes of nutrition.

Table VIII shows that apart from the initial count in 1942, egg-count levels were not seriously high and also that, as was the case during the lamb fattening trial, they decreased rapidly as the winter advanced.

Drenching with phenothiazine in both 1942 and 1943 brought about weight gains that were significant at the one per cent level. The differences in other years were not significant.

No satisfactory explanation can be offered for the anomalous response to drenching in the years 1942 and 1943 when in the first instance hoggets with fairly high initial counts responded only in a slight degree, and when in the second instance hoggets with lower counts responded more favourably. This being so, no clear critical level of egg-counts in hoggets can be presented, although it does appear that a small response to drenching may be expected when egg counts in May and June show figures above 1,000 eggs per gram. However, it must be stressed that the small differences in body weight obtained in the trials, although statistically significant, are unlikely to be of any commercial value.

One further experiment may properly be reported here, viz. one conducted during the late autumn of 1947 when one group of 66 ewe hoggets suddenly developed symptoms of advanced internal parasitism. The sheep concerned were a group deliberately poorly fed in an experiment which does not form one of the series already referred to in this paper, and which had as its object the investigation of the effect of high and low planes of nutrition on the growth and development of

TABLE VIII. MEAN FAECAL EGG-COUNTS AND WEIGHT-GAINS PER DAY OF HOGGETS 1941-5

Year.	Treatment.	No. of samples.	No. of eggs per gram of faeces.					Weight gain in lb. per day.	
			May.	June.	July.	Aug.	Sept.	High plane.	Low plane.
1941	drenched P20g	28	744	855	180	50	50	0·25	+0·01
	control	28	540	850	520	350	140	0·24	—0·01
1942	drenched P20g	40	2,080	1,435	340	220	200	0·16	+0·12
	control	40	2,120	1,375	570	530	470	0·14	+0·09
1943	drenched P20g	48	730	830	350	290	110	0·13	+0·03
	control	47	1,000	1,190	570	270	290	0·08	—0·02
1944	drenched P20g	16	565	780	360	10	20	0·18	+0·08
	drenched P40g	16	825	300	150	35	20	0·16	+0·12
	control	16	950	1,630	430	180	20	0·15	+0·06
1945	drenched P20g	20	480	—	—	—	110	0·16	—0·01
	control	20	650	—	—	—	450	0·17	—0·04

Corriedale sheep. The sheep had been kept from birth in one paddock of short, very poor pasture of brown-top (*Agrostis tenuis*), hair-grass (*Vulpia bromoides*), and stunted subterranean clover (*Trifolium subterraneum*), and had made no weight gain since the previous December. Suitable weather conditions brought about a rapid growth of subterranean clover, and within a short time the sheep began to scour; they lost condition rapidly and some deaths occurred. The remaining animals were immediately weighed and faecal samples for egg-counts were taken from each one. The mean weights showed a recent loss of 8 lb. and the mean egg-count had risen from 180 eggs per gram in February, when a routine check had been made, to the extraordinarily high level of 8,100.

It was decided to split the group and carry out an experiment to study the effects of improved diet and drenching. However, as the hoggets were primarily on a low plane of nutrition and as it was undesirable to improve their diet for too long a period, the experiment was terminated after six weeks. Table IX summarizes treatment, initial and final weights, and egg-counts of these sheep, divided on a weight-basis into four groups of 15 sheep. Four groups were fed 1 lb. of hay per sheep per day to prevent further drastic mortality.

Groups 1 and 3 received phenothiazine before going on to feed, and again three weeks later.

Five hoggets died during the experiment, three in Group 4 and one in each of Groups 1 and 3. All showed very high worm egg-counts, the highest being 73,800 eggs per gram. These figures, however, are not included in the mean figures given in the table.

An analysis of variance showed that the weight improvements brought about by better feeding and drenching on both types of feed were significant at the one per cent level.

As no other sheep on the farm were affected, it seems probable that starvation was the primary cause of this outbreak. Either improved feeding or drenching with phenothiazine checked the progress of the outbreak which was completely eliminated when both treatments were used together.

TABLE IX. INITIAL AND FINAL WEIGHTS AND EGG-COUNTS OF HOGGETS

Group.	Feed.	Treatment.	Initial weight 24/4/47. (lb.)	Final weight 4/6/47. (lb.)	Initial egg-count 24/4/47. (e.p.g.)	Final egg-count 4/6/47. (e.p.g.)
1	Lucerne aftermath	drenched twice—30g. phenothiazine	48·3	59·5	7,830	340
2	Lucerne aftermath	undrenched	48·3	53·1	6,660	2,340
3	Original pasture	drenched twice—30g. phenothiazine	48·3	54·5	4,640	460
4	Original pasture	undrenched	48·5	50·2	6,060	3,380

DISCUSSION

Considered together, the results of all the above trials offer confirmation of the hypothesis that there is an intimate relationship between climate, nutrition, and infestation with pathogenic nematodes, but there still remains the difficulty of determining in any particular season whether anthelmintic treatment of sheep is likely to be necessary or not. It would appear that the critical level is in the vicinity of 2,000 eggs per gram of faeces for the trichostrongylid species infesting lambs in Canterbury. Such a mean faecal egg-count is likely to be attained when the spring, especially the months of November and December, is both wet and warm. When a majority of either unweaned or weaned lambs give faecal egg-counts of this magnitude, drenching appears most likely to result in significantly better weight-gains.

The extensive series of total worm-counts made during the field survey, and the additional information given by the subsequent experiments at Kirwee, indicate that although *Ostertagia* spp. are generally

present in fairly low numbers in sheep of all ages, it is *Trichostrongylus* spp. which are found in dangerously high numbers when climatic conditions favour worm multiplication. It is then that the well-known clinical picture associated with severe worm infestation is seen, a more or less intense unthriftiness associated with lack of appetite, depression, and, in most instances, a persistent diarrhoea and a desire for water.

During the years of these experiments, the level of worm infestation in ewes remained very low. There was no occurrence of that rapid increase in worm numbers which has been found to occur in the occasional years of high sheep mortality, mostly in ewes suckling twin lambs some eight to ten weeks after lambing.

As the winter advances with consequent low temperatures there is a sharp falling-off in infestation and this is responsible for the low faecal egg-counts observed in most winters in hoggets. The evidence provided by the short autumn experiment with hoggets on a low plane of nutrition in 1947, suggests that only when there has been severe prior lowering of the plane of nutrition, as well as concurrent favourable weather conditions for worm multiplication, will there be interference with the growth-rate and a favourable response following drenching.

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